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LIEUTENANT R. R. INGERSOLL, U. S. N., in the Chair.

THE MOST SUITABLE METAL FOR NAVAL GUNS.

By WM. J. MCALPINE, Consulting Engineer; Past President American Society of Civil Engineers; Member of the Institution of Civil Engineers of London.

Mr. Chairman and Gentlemen:—I have read with great interest the discussions before the Institute in regard to the qualities of the steel which should be used for the fabrication of large guns for the Navy. I have heretofore written a letter to one of the members of the Institute, and, at the request of the Secretary, embody the opinions therein expressed in the following paper.

My studies have led me to different conclusions from many of those expressed in Mr. Dorsey's paper before the Institute. The terms "mild" and "hard" steel do not of themselves convey a sufficiently definite distinction in the grades of steel. Mr. Dorsey, however, defines his use of the term "mild steel" as a metal "having a very low percentage of carbon, incapable of taking temper, etc., and having a tensile strength of from 55,000 to 65,000 pounds"; and of "hard steel" as having "a variable percentage of carbon, will take temper more or less hard, and having a tensile strength of over 90,000 pounds."

The alloys of iron—cast, malleable, and steel—are often colloquially distinguished by the proportion of carbon in combination* with metallic iron. Thus, the first product from the ore (cast iron) contains generally about four per cent. of carbon; the second (malleable iron) is produced by the removal of most of the carbon; and the third (steel) by recharging the metal with carbon.† Each of these processes refines the metal, and the last product gives to steel its highest comparative value. Another distinction is that the alloy which has no carbon is fibrous, and with carbon is crystalline. The value of each of these alloys of iron depends primarily upon the quality of the ores, and next upon the subsequent manipulation of the metal.

The additional charge of carbon, within limits, increases the tensile strength, elasticity and hardness, and, if proper skill and care are taken in the manufacture, the different grades of steel should have an equal degree of "reliability." If they do not, the fault is that of the manufacturer and not of the material. In like manner the size of the mass of any of these alloys, when properly manufactured, need not affect its reliability;‡ where it does so, it is again the fault of the manufacturer.

Cast iron and steel of all grades become fluid at a much lower temperature than wrought iron, and in proportion to the quantity of carbon which they contain.§ The differences of temperature which these several alloys require in the process of manufacture, require a different treatment for each, and when this treatment is made appropriate to steels of different degrees of carbonization, it will doubtless, under similar conditions, produce metals of equal reliability. Experienced manufacturers understand this, and the "capriciousness" of some steel in the market is probably due to inexperience, ignorance, or neglect. The rigid inspection of the ordnance officers would exclude the use of such improperly made steel.

* Not necessarily in its chemical sense. Some metallurgists believe that the mixture is a combination producing a new metal, but generally steel is considered as having only a mechanical union. Dr. Seeman considers steel as simply a union between carbon and metallic iron, and manganese, silicon, etc., as impurities of the alloy.

† The alloy is usually called "cast iron" if the proportion of carbon exceeds two per cent., and "malleable iron" if it contains less than one-fifth of one per cent. of carbon.

‡ By reliability I do not mean *absolute* strength.

§ Cast iron becomes fluid at a temperature of about 1900 to 2700 degrees Fahr.; steel at 2600 to 3300, and malleable iron, formerly considered as infusible, melts at about 4000 degrees.

The use of the oil bath is to suddenly chill the metal while it is in the condition of high temperature, when its crystallization is in a uniform and minute form; it being claimed that if the mass is allowed to cool slowly, the interior crystallization becomes coarse and irregular. The bath, whether of oil or other fluid, chills the exterior first. The subsequent cooling of the interior, while under the pressure of the cooled exterior shell, brings strains which must be subsequently removed by annealing. The effect of the bath extends as deep into the metal as the change of temperature. It appears to me that a process of manufacture which would prevent any material difference of temperature between the exterior and interior during the process, would secure equal strength and character throughout.

In the construction of guns, it is desirable to have the "tube" or inner cylinder of a metal which, with the other requisites, will best resist the wear and tear of the shot and gases, and hence two kinds of metal are necessary; but if thick masses of steel of the required quality, and homogeneous throughout, can be manufactured, the gun will be stronger if made of two than of any greater number of rings.

Some years since, I witnessed the perforation of a wrought-iron shield (composed of two plates of 7 and 8 inches thickness bolted together) by a shot of 624 pounds from a 12-inch Rodman rifle. At the edges of the shot-hole the welded plates, each of an inch thickness, were torn apart by the blow of the shot, 6 inches back from the hole. In a gun made of many thin hoops, the welding would not make as complete union as the metal itself has, and the strain produced by the shrinking of the hoops upon each other might be detrimental to the strength of the gun; but this opinion I give with some diffidence.

The difference in the cost of manufacturing an equal quality of steel of low or high carbonization is inconsiderable. When prepared for bridge-work the metal is worth about $50 a ton, and $10 more to put it into the finished work. The cost of the completed steel gun is said to exceed $500 a ton. The elastic strength of so-called "mild steel" with one-eighth of one per cent. of carbon is but three-fourths of that of steel with the half of one per cent. of carbon. Hence, guns made of metal of the former description would weigh nearly a third more than those of the same strength made of the latter metal. This lessened weight of each gun of the stronger metal, would enable a ship of war of any given displacement to increase largely her armament.

I enclose a copy of the specifications* of the Harlem Bridge, now in process of construction, of which I was the engineer. It will have two arches of 500 feet span, of mild steel. The specifications for the metal-work were prepared by Mr. Theodore Cooper, the consulting engineer.

In a railway bridge of a certain span, half of the strain is produced by the constant static load—viz.: the weight of the bridge itself. The effect of the sudden entrance of a train at high speed constructively produces an equal strain.

*STEEL.—The steel shall be uniform in character for each specified kind. The finished bars, plates and shapes must be free from cracks on the faces or corners, and have clean, smooth surfaces.

All steel for the arch ribs, girders and tension rods shall have an ultimate strength of 62,000 to 70,000 pounds per square inch, with an elastic limit not less than 32,000 pounds per square inch, and a minimum elongation of 18 per cent. when measured on an original length of 8 inches.

All steel for rivets shall have an ultimate strength per square inch of 56,000 to 64,000 pounds, with a minimum elongation of 25 per cent.

Tests shall be made by samples cut from the finished material after rolling. The samples to be at least 12 inches long and to have a uniform sectional area not less than ½ square inch. All the samples must show uniform fine-grained fractures of a blue steel-gray color, entirely free from fiery lustre or a blackish cast.

Samples cut from finished material for the arch ribs, girders or tension members, tested before or after heating to a low cherry-red, and cooled in water at 82° Fahr., must stand bending to a curve whose inner radius is one and a half times the thickness of the sample without cracking. Samples of rivet steel, before and after being heated to a light yellow heat and quenched in cold water, must stand closing solidly together without sign of fracture. To check the uniformity of the material, the manufacturers of the ingots shall cause to be made from each cast sample bars of ¾ inch round, with a definite and uniform reduction equivalent to reducing a 4-inch ingot to the sample size. They shall mark the same in a manner to identify the final product.

The usual chemical tests shall be furnished in connection with these samples.

No work must be put upon any steel at or near the blue temperature, or between that of boiling water and the ignition of hardwood sawdust.

Any steel straightened or worked cold by use of the hammer or gag press must be afterwards wholly annealed.

The contractor must furnish the use of a testing machine, capable of testing the above samples, at all mills where the iron or steel may be manufactured, free of cost.

All facilities for inspection of the material and workmanship shall be furnished by the contractor. He shall furnish the above samples, prepared, of both the steel and iron, without charge.

The strains to which large guns are subjected are very different in time* and degree, as well as the static weight of the structures which receive them. The explosion of the powder creates an almost instantaneous radial pressure upon the metal surrounding the chamber of a ten-inch gun, of perhaps five or six hundred tons per lineal inch of its powder-chamber length, while the weight of the gun itself is comparatively very small. This differs from the engineer's bridge in the intensity of the strains produced, in the time occupied in their development, and in the capacity of the structure to receive and absorb them.

The cheapness of mild steel and its considerable tensile and elastic strength render it suitable for a bridge structure, but for a gun the elasticity and ductility of the metal to receive the first shock is the primary consideration. Subsequently, and immediately afterward, the tensile strength of the gun metal is called into requisition. For this purpose, therefore, steel of the greatest elasticity is first required, and next of the greatest tensile strength.

Experience has demonstrated that steel of about one-third to the half of one per cent. of carbon, with an elastic limit of not less than 50,000 pounds and ductility of 15 to 20 per cent., made from ores of the best and most suitable quality and manufactured with the greatest care and skill and properly bathed and annealed, is the most suitable metal for the fabrication of large naval guns.

NOTE.—I have now in hand the construction of a bridge of two steel arches of 500 feet span, in which will be used 7000 tons of iron and steel; also the Arcade Railway, on the first section of which (five miles) there will be used 60,000 tons of iron and steel. During the past year I have also prepared plans for a steel pipe of ten feet diameter and two miles long, and on another work for steel pipes of three feet diameter and thirty miles long. For each of these works I have considered that mild steel is the most suitable material. You will therefore perceive that I am not opposed to the use of that quality of metal in its appropriate place.

DISCUSSION.

THE CHAIRMAN.—It is not my purpose to take up any time in attempting to add to what has already been so ably said by the lecturer on the subject of steel for heavy guns. It is easy to account for the fact that but little discussion is volunteered; for this audience, or at least the naval part of it, is, perhaps,

*The conversion of the powder into gas is said to occupy $\frac{1}{4000}$ part of a second, and the pressure developed 15 to 20 tons per square inch.

already prejudiced in favor of just the grade of steel that Mr. McAlpine has advocated as proper to use. Besides being a very instructive paper, it fortifies the position that ordnance officers have taken in demanding a high grade of steel for guns. It is also a matter for congratulation, especially to those who have hitherto defended steel of high grade, to have this endorsement of their views from such undoubted authority.

I am sure all will join me in the agreeable duty of expressing the thanks of the meeting to the lecturer for the pleasure and instruction that he has afforded us.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

THE NAVIGATOR'S POSITION INDICATOR.

By Lieutenant H. O. Rittenhouse, U. S. N.

The navigator's position indicator is an instrument designed to indicate the position of a vessel when navigating coasts or inland waters where towers, buoys, lights, beacons, or other marks may be seen and recognized. Briefly, it is an instrument whose principal use is to lay down quickly and accurately one or more lines of bearing.

Even under favorable circumstances, and when there is ample time to take the observations and perform the necessary chart work with due care, the method in general use at present can lay but little claim to accuracy. Compass observations are taken generally to the nearest quarter point only, with more or less interval between observations. These bearings are *corrected*, using again the unit of quarter-point instead of the degree. With these approximate bearings the navigator begins work upon the chart with the pencil and parallel rulers. It is difficult to adjust the ruler accurately to the compass diagram, especially if it is marked to half-points only, and it certainly requires time and usually much skill and experience to prevent the ruler from slipping before the line can be drawn. The entire process in all its details must be repeated for the second line.

By use of the position indicator great accuracy is attained, and the time of taking an observation and plotting the result is reduced to a minimum. It consists of a chart table fitted to revolve in a horizontal plane, and capable of being adjusted so that the meridians of the chart which it carries can be brought into parallelism with the corresponding meridians of the earth's surface. Upon a chart so adjusted the direction between any two indicated points is identical with the true direction between the corresponding actual points which the chart represents, and the chart table is technically said to be *in position.*

A vertical standard and pedestal is secured to the deck in a convenient place for taking observations. This standard carries at its upper extremity a fixed metal circle, or dumb compass, of 16 to 20 inches diameter, graduated to degrees, and fitted with an adjustment to compensate for heeling of the ship when necessary. The chart board pivots over the centre of this circle and is supported by it. The standard is secured to the deck so that the initial point of graduation of the circle is in a fore-and-aft line with the centre of rotation, similar to the position of the lubber's point of a compass.

The chart board, which is rectangular in shape, has a metal plate secured to its under surface adapted in form to the upper surface of the fixed circle, and fitted to rotate over it. An index attached to the board moves over the graduation of the circle, and thereby may be set at any desired point of the graduation by a set screw or clamp. The chart is secured to the board so that its meridians coincide in direction with the index.

The station pointers consist each of two parts: First, the station centre, which is a metal cylinder of sufficient weight to maintain its position on the chart when subject to the usual disturbances of wind and other causes. This cylinder is hollow, and fitted with cross-wires near the under surface, by which means it is accurately placed over any specified object on the chart. Second, fitted to revolve upon the station centre is the *pointer*, which has two arms, one carrying the sight vanes, while the other is a simple straight-edge lined with the intersection of the cross-wires, and corresponding in direction with the line of the sight vanes. This straight-edge is raised just clear of the chart, so as to revolve with ease, and also lie conveniently for drawing lines defined by it. A thin washer raises it more when necessary.

The chart having been placed in position upon the board, the station centres and pointers are adjusted over the objects on the chart upon which the observation is to be taken. The standard compass course, or heading of ship if at anchor, is then observed, and the true course found to a degree by applying the necessary correction. Set the table *in position* by moving the index to the number of degrees indicated by the true course and clamp it. The pointers are then turned upon the designated objects, and the crossing of the straight-edges indicates the ship's position directly. Lines may be drawn by the pencil or not, to suit the pleasure. A series of observations may be taken in rapid succession, and the track of the ship traced almost by a continuous line.

Increased accuracy over the ordinary method results from the fact that the ship's head and the necessary corrections are all noted without difficulty in degrees. Moreover, when the sight vanes are ranged on the observed object, the line of bearing is already indicated without additional discrepancy.

Vessels of modern speed manœuvring in bays or estuaries could ill afford to lose the time required to read bearings, manipulate the rulers, and permit the observer to pass to and fro between his chart board and the compass. In critical situations the effect of a tide, or current, or a drift of the vessel from any cause, could be readily detected by the indicator.

Slight modifications of the use of the instrument as above described will suggest themselves to the operator. Thus, to insure the chart board being set *exactly* to the course, it is well to adjust the chart board as above described, and let an assistant (the quartermaster) call out when the vessel is exactly on her course. The observation taken then will give the position with great accuracy.

Still greater refinement (possibly of use) is secured by having two observers, one at each pointer, to observe simultaneously. By this means the error due to travel of ship between observations is eliminated. This error cannot well be eliminated from the method by compass bearing, as that instrument is fitted for use by one observer only at a time.

When from accident or design one (or both) of the station centres should not be over the represented object on the chart at the time of observation, it is apparent that the *direction* of the bearing thus obtained is correct, and it may be easily transferred parallel to itself to its true position. The instrument is well adapted to making rough or running surveys, and the station centres and pointers can be used on an improvised plane table for ordinary surveying purposes on shore, giving results the accuracy of which would be inferior only to refined work.

The fixed graduated circle operates with the standard compass, enabling us to turn the chart table in an opposite direction through the angle which the keel is turned away from the meridian. This suggests the advisability of adjusting the zero point of the graduated circle to correspond with the lubber's point of the standard compass rather than to adjust it in a fore-and-aft line by means independent of the compass. The harmonious adjustment of the two instruments eliminates any error due to displacement of the lubber's point.

The use of the chart table ceases when the vessel is out of sight of sailing-marks. It is then dismounted by lifting it from the fixed circle. The circle, however, retains its uses, and the following modifications and suggestions are advanced as tending to facilitate the work of the navigator and officer of the deck:

A suitable station should be provided on every ship, affording an uninterrupted view of the horizon, where the captain, navigator, pilot, or other person responsible for the conduct of the vessel while under way, may perform his duty to the best advantage. The narrow bridges on our men-of-war, which, on important occasions, are apt to become the disputed territory of no less than three officers, and sometimes half a dozen, are not well designed to meet the requirements above mentioned. An offset from the bridge of six or eight feet square, preferably a little higher than the bridge and communicating with it by steps, would, in many cases, answer the purpose. Just where it should be located on a particular ship, however, is subordinate to the consideration that it should be located *somewhere*. In places of difficult navigation, and in fleet and squadron drills under way, it is a necessity, and on ordinary occasions, both at sea and in port, it would be in constant use for lookout purposes.

The dimensions above stated give sufficient space in which to set up a dumb compass, mount a chart board, and give room to move about and operate them. The design of the position indicator embraces the use of a dumb compass in the following manner:

The dumb compass consists of two discs or circles; the under one, fixed in position, and having its zero mark to indicate the direction of the keel, being the same as previously described as part of the position indicator proper. The upper one revolves over the lower and carries an index and clamp, and is graduated to degrees and to quarter-points. The lower disc is used as a means of setting the upper one to correspond with the course. When the index is set to any course indicated by the graduation of the lower disc, the upper disc becomes practically a *live* compass while the vessel continues on such course, and all bearings noted by the upper disc are ready for application to the chart. When the index is set to the *true* course, the bearings obtained are *true* bearings; when set to the *magnetic* course we have *magnetic* bearings, and when set to the *compass* course we have *compass* bearings.

Over the upper disc are pivoted two alidades with sight vanes, working independently of each other, and permitting two bearings to

be taken simultaneously. Set-screws clamp them at will. It will be observed that the entire work may be carried on by degrees instead of quarter-points, no reduction is applied to the reading, and when the vessel is going swiftly simultaneous observations eliminate the usual error due to interval of time.

By means of the binding-screws the two alidades can be set at any desired angle with each other, as, for instance, in the problem of keeping the vessel outside the danger angle, or in navigating curved channels on the arc of a circle by a single angle, described by Commander H. C. Taylor, U. S. Navy (Proceedings U. S. Naval Institute, No. 37).

In fleet evolutions the two alidades, set at right angles with each other, would give both bow and quarter bearings without changing the adjustment. In simpler formations it would give ahead and astern and beam bearings, and at high speeds would be of great use in determining and preserving bearings and intervals. The use of such dumb compass would substitute a refined and accurate instrument for the rude lines scribed or painted upon the decks and bridges of ships.

In inshore navigation, when it becomes desirable to use the chart on deck, we have simply to unship the alidades, lay the chart board on the upper disc, and secure it by the same central bolt which previously held the alidades. The position indicator is then ready for use, the two pointers taking the place of the discarded alidades, and indicating on the chart the line of bearing as soon as observed.

It will be noticed that nothing whatever in the appliances here suggested interferes in the slightest manner with the use of compass bearings and parallel rulers, when from any cause such method is preferred.

The principle upon which the instrument is based is exceedingly simple, and has been familiar to navigators and surveyors for a long time. It is the basis of "A New Method of Making Running Surveys," described by Ensign J. H. Fillmore, U. S. N., in No. 33, Proceedings U. S. Naval Institute, and an excellent description of it is given by M. Delafon in the *Revue Maritime*, May, 1885.

The application of the principle as hereinbefore described is obviously but a modified form of the surveyor's plane table. This instrument has been highly developed by the officers of the U. S. Coast Survey, and the report of that office for 1880 contains a complete description of the instrument and its uses. Its great capacity for locating positions, the readiness with which it is adapted to the various problems in surveying, and its harmonious combination of

the qualities of convenience, accuracy, and dispatch are the chief reasons for the preference given it over all other instruments for the purpose; and this preference is a most significant proof of the value of the principle.

As an illustration of the facility with which the instrument can be applied to problems in navigation, it may be mentioned that, independent of the compass, it furnishes a practical solution of the three-point problem without measuring the angles or using the protractor. Thus: Put the chart-table *in position* as nearly as possible by the eye. Place the station centres and pointers over the three objects, A, B, and C on the chart, draw bearings to the real objects which they represent, and denote these lines respectively by a, b, and c. If now we use the dividers, the perfect solution is obtained by the intersection of the two circles, one through A, B and the intersection of a b; the other through B, C and the intersection of b c.

If, however, we do not wish to work with dividers, but confine ourselves to straight lines, we obtain an approximate practical solution as follows: After drawing a, b, and c as before, change the adjustment of the board slightly (turn the board in the direction to make a better adjustment to the meridian if possible) and draw new bearings, a', b', and c'. a and b meet in a point K; a' and b', in a point K'. Similarly, b and c meet in a point L, and b' and c', in a point L'. Join K and K', also L and L'. The intersection of these two lines is the practical determination of the observer's position. [Many other methods can be used; for which see U. S. Coast Survey Report, 1880.]

Its success in practice depends, of course, upon the good qualities and careful adjustment of the compass with which it is used; and even if the compass corrections are not accurately known, the indicator can give *no worse* results than the ordinary compass method. The ship's compass of the present time is so much improved, and, with ordinary attention bestowed upon it, is so reliable an instrument, that no objection to the use of the position indicator could arise from such consideration. I enjoyed the opportunity last summer, on the U. S. S. Jamestown, of experimenting with the instrument in a modified form, such as could be conveniently made on shipboard, and the result of these experiments fully justified my expectations. The use of accurately constructed instruments utilizing this principle, whereby the ease, rapidity, and accuracy of ordinary chart work are greatly increased, would fully supplement the efficiency of our compasses.

U. S. NAVAL ACADEMY, *January* 1, 1887.

Fig. 1.

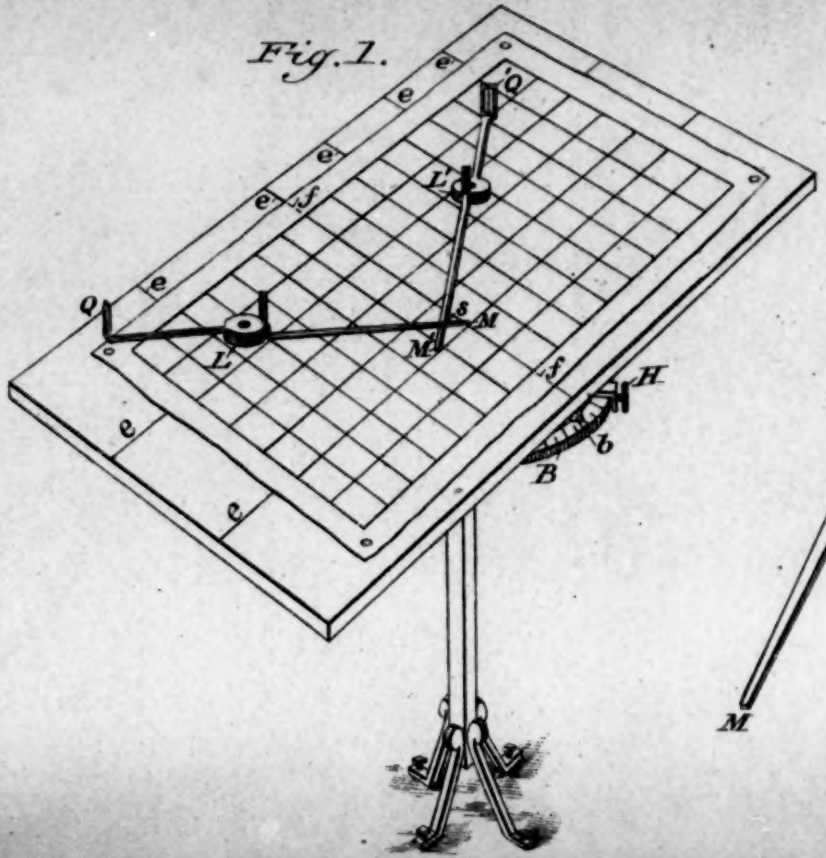


Fig. 2.

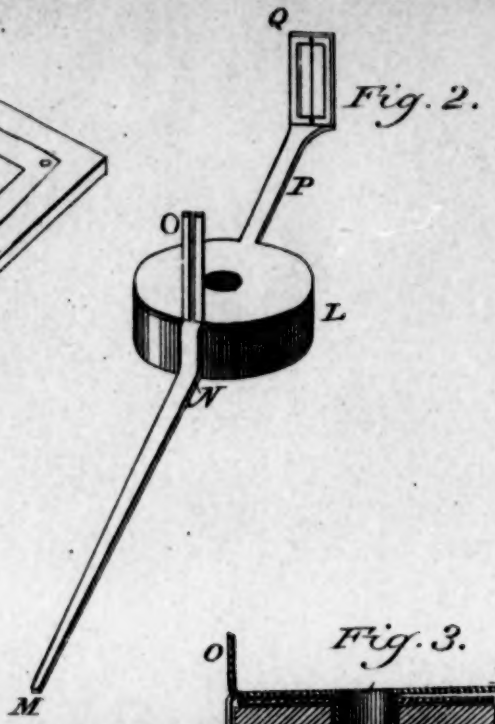
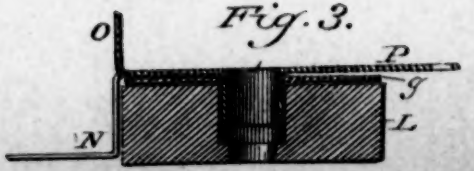


Fig. 3.



The accompanying diagrams show the principal features of the instrument:

FIG. 1.—Perspective of the chart table when in use.

B, fixed circle secured to upper extremity of the standard.

b, index
H, clamp wheel } attached to chart table.

e f, *e*, *e*, etc., permanent lines drawn on upper surface of chart table for convenience in securing the chart in proper position. [A meridian (or parallel) of the chart is continued over the border and made to coincide with one of the lines.]

L, *L'*, station centres upon which revolve the pointers.

MQ and *M' Q'*, pointers indicating the position of the observer at *S*, where the right-hand edges of the pointers intersect.

FIG. 2.—*MNOPQ*, pointer shown in position over station centre.

FIG. 3.—Section of same.

g, thin washer for raising the straight-edge *MN* when necessary, that it may move freely over the second edge *M' N'*.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

MARCH 4, 1887.

COMMANDER W. T. SAMPSON, U. S. N., in the Chair.

PRESSURE-RECORDING INSTRUMENTS.

BY JARVIS B. EDSON, M. E., OF N. Y.

Mr. Chairman and Gentlemen:—The brief time I shall ask your attention this evening precludes the possibility of my devoting any attention to all of the various instruments and appliances for indicating and recording fluid pressure. I shall therefore limit myself to the consideration of that class of instruments which have been brought forth as reliable, and applicable to pressures varying from an absolute zero to that of a few thousand pounds per square inch (*they* forming those of the most extended manufacture and use in the daily arts), and conclude with a few words on their application and desirability.

Instruments for only indicating pressure have been made under two general types—that of the bent tube, after Bourdon, and that of the vibrating diaphragm, from the German. These move according to the fluctuating pressure applied, and such movement I term "original travel." The pressure upon them is determined by the mercury column as a standard, and their scales and dials are laid off accordingly. Starting with the assumption that the mercury column is accurately constructed and properly used, we have to consider the form and appropriateness of the metals employed in these two types for sustaining without change or "set" constantly varying strains and shapes so that similar exposure to pressure shall result in similar travel and dial-reading. The two types mentioned have, as a rule, predominated for indicating purposes in about equal numbers, and been accepted as equally trustworthy and reliable by the masses, who neglect to question or probe beneath the surface. When we consider that the

duty is that of a spring, based upon the resilience of the metal composing the same, it seems somewhat strange that the Bourdon tube, made of brass composition, should even be expected to act equally with the properly tempered disks of steel. Ordinarily, where the vicissitudes of its use admit of the same, we invariably employ tempered steel when we want a spring, as we know more about making it of that metal than we do of alloys of copper, tin, etc.; and in practice the failure in the Bourdon tube is due to the yielding of the metal composing it, while the steel diaphragm, when well made, has an endurance which nothing but tempered steel can give. Unfortunately, however, these diaphragm instruments have been poorly made both as to the spring and the multiplying mechanism for throwing the hand around the dial. Nor does the most difficult portion of the problem consist in simply providing a reliable spring, because it is equally important to have a uniform and lively "travel" from the pressure itself, in order to dispense to the utmost degree with the introduction of multiplying gears, which multiply errors as readily as they do the "original travel." Of equal importance is it, also, that the *persistence* of the "travel" shall be able to overcome the friction to be encountered in moving the multiplying and indicating mechanism. This persistency of change, due to the variable pressure in the *tube*, is extremely slight, and in the *diaphragm* very great. In the latter it is determined by multiplying the exposed area of the diaphragm by the pressure in pounds per square inch it is sustaining. As friction must be overcome and work done without disturbing the accuracy of the instrument in its movement, this "persistency of travel" possessed by the diaphragm alone is a very important feature. Therefore it is sufficient for our present purposes that we take into account only the consideration of steel diaphragms and their superincumbent mechanism for giving multiplied travel to the hand upon the dial.

By custom, for commercial purposes, they have been made of French and English steel, varying in thickness according to the pressure to be sustained, and cut into small disks two and one-half inches in diameter, and corrugated slightly to increase their displacement under various pressures. Such disks give a travel of only one thirty-second of an inch. No reason is to be found why this small diameter was selected, or why it has always been adhered to. The total "original travel" from the pressure itself must be proportionate to the diameter, and while a greater travel is always ultimately required for dial purposes, it has only been obtained through high multiplica-

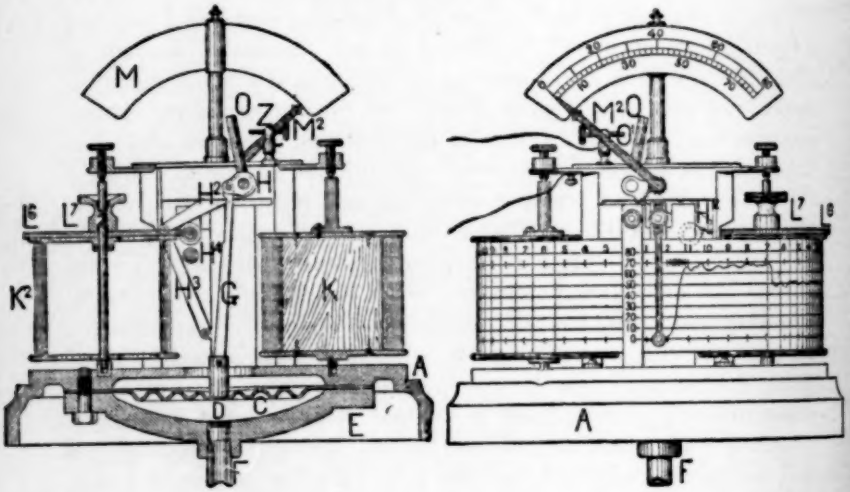
tion, by gearing of the small "original travel," and at the expense of durability and accuracy.

My attention was called to this matter in 1869 or 1870, and soon discovering that the diaphragms in use were improperly constructed, I at once introduced two improvements, which consisted in corrugating the diaphragms convexly, and increasing the dimensions and amplitude of such corrugations from the centre to the circumference. This resulted in more than doubling the "original travel" previously obtainable from a given diameter and thickness of disk under similar pressure. Thus encouraged, I increased the diameter from two and one-half to six and one-half inches, obtaining an "original travel" directly from the pressure itself, without multiplication, of from three-eighths to one-half an inch. With an abundance of travel, I also had a "persistency of travel," unaffected by any reasonable amount of friction to be encountered in moving an indicating or a recording mechanism. In fact, at this point started the present recording apparatus, after the continuous failure of many others, here and abroad, in their attempt to get a competent and durable source of "original travel" suitable for a pressure-measuring and recording mechanism. That the problem then received no meagre solution is attested by the fact that the type of pressure recorder here exhibited has been in extensive use since 1875.* On the other hand, while the pressure-recording instrument has been steadily making a record of reliability for itself, the simple indicating gauge has as steadily pursued a retrograde course, until now the commercial instrument is so carelessly standardized, if standardized at all, that reliance upon it becomes positively dangerous, and cannot be too strongly deprecated. In fact, the eminent engineer, the late J. C. Hoadley, as one of a committee appointed to compile a code of rules to be adopted in making steam-boiler tests, specifies an Edson recording gauge and its record as a good check upon the indications of the ordinary steam gauge. So in the report for August, 1885, of the inspectors of the Hartford

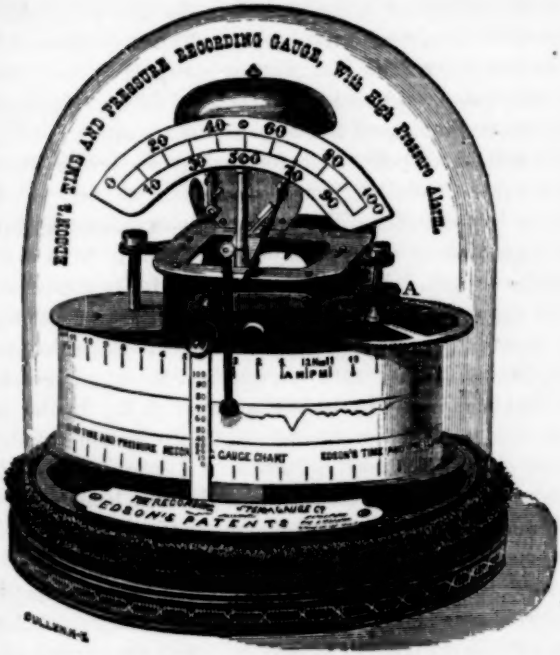
*These instruments were accepted by the Government authorities as being in full compliance with the law of Congress requiring steamers to carry pressure-recording gauges; were used by the special board of experts in their extensive and crucial boiler tests at the Centennial Exhibition in 1876, and met the approval of the special expert in charge; were ordered to be used in the United States Navy, after trial and test by the Engineering Department; were adopted by the British Admiralty in large numbers, and by the Government buildings in Washington and many other cities; also on transatlantic steamships, etc.

Steam Boiler Insurance Company, they give: 255 pressure-indicating gauges defective—31 dangerously so—and 2 boilers *without* them; report for April of same year gives 169 defective, 42 dangerously so.

The instrument referred to, briefly described, consists of a metal base *A*, enclosing beneath it a tempered diaphragm *C*, so arranged that when the fluid enters the space *D* between the spring and the cap *E*, forming the chamber, the spring is deflected upwardly. The recording apparatus is mounted on the top of the base *A*, and the movement of this diaphragm *C* is transmitted through the arms H_1 and H_3 on the rock shaft *H*, by means of the connecting bar *G*, to the vertical moving pencil carrier in front, thrown thereby about six



times the original travel of the diaphragm. Simultaneously therewith, motion from the same rock shaft *H* moves the hand M_2 before the dial *M*. A special clock mechanism revolves the receiving reel K_2, contributing the element of time to the chart drawn from the reservoir reel *K* on the left, beneath the recording pencil. Ordinarily this reservoir reel *K* contains a supply of charts for thirty days. A glass dome surmounting the whole enables inspection and excludes dust, moisture, etc. The supplemental, adjustable arm *O* upon the rock shaft *H* acts both as a circuit closer for an electro-magnetic alarm, and operates a mechanical alarm usually provided with each instrument.



This form has been found successful in recording pressure from two pounds per square inch for blast furnaces, to (1200) twelve hundred pounds per square inch used in pumping oil. For recording temperatures of drying-rooms, etc., a supplemental diaphragm is employed to increase the travel, owing to the low coefficient of expansion possessed by the fluids used for the various temperature ranges.

I take it that, of all the various uses to which pressure-recording instruments are put, none equals in importance, practically, that of being called upon to stand sentinel over the pressure of steam. Certainly no other explosive element is encountered so frequently, or enters so largely into our domestic economy; and equally true is it that no other is produced in such ignorance or left to such carelessness. Attendant safety and economy are almost entirely left to become matters of chance, and while the average steam user readily accords due homage to a pound of gunpowder known to be stored about his establishment, willingly assuming it to be dry, he cannot be made to believe that each cubic foot of water in his boiler under sixty pounds of steam contains the explosive energy of that same pound of gunpowder. Equally true is it from an economical point of view that

the stoker who will labor the cheapest is the cheapest laborer to his mind; and while ready to denounce as extortion a demand for an increase of wages of even five per cent. on the part of the boiler attendant, he readily pays, unquestioned, any coal bill at sight, though its excess may more than equal the wages of the man.

A well-constructed boiler, proper firing, moderate draught and steady feed—these form the basis of the best economy. The pressure of steam in the boiler will vary from two causes—upwardly from excess of supply over demand, and downwardly from the demand exceeding the supply. Now, if the demand be constant, there is no reason why the supply should not be constant also. If, on the other hand, the demand for steam is variable, does it follow that the supply should also become inconstant? Inequality in *demand* may be regular and right, but inequality in *supply* is never right, for the conditions which give rise to it are almost invariably attributable to carelessness or ignorance or inexperience. This is, to a large extent, the natural consequence of the peculiar conditions under which steam is generated. The idea prevails that, to obtain steam, *coal must be burned*, and in order to practise frugality the *cheapest labor* must handle it in the fire-room; while by the same intelligence the conclusion is reached that the *engine* must be presided over, for *economy's* sake, by a skillful and experienced man—of necessity! But we are not all ignorant of the relative stewardship of the boiler with the coal supplied it, and the engine with the steam it gets; and the time may not be far distant when, copying the practice from the Caspian Sea and substituting oil for coal, we may not only better *use* our fuel, but bring mechanical appliances in play which will be much more reliable than careless or ignorant human agents can be. The most ordinary intellect would at once intuitively, as it were, recognize the necessity for supplying the stream of oil in just the proper quantity uninterruptedly, and would strive to preserve the proper adjustments of the apparatus for its accomplishment; while the same person, if using coal as a fuel, would entirely ignore the extra necessity for vigilance and attention required to maintain a steady supply of it, and a uniform rate of its distillation into the gases of combustion. That from five to thirty per cent. of the fuel used for a given steam production can be saved or wasted, never occurs to the average fireman or his employer; and, therefore, the fidelity to duty imposed upon him by the knowledge of the operation of the pressure-recording gauge compels him to give the utmost attention to his work, and so, incidentally, to practise economy.

Once, during a three years' cruise in the "service," just after the close of the war, I took the trouble to compare the amounts of coal burned by the different watches for a continuous period of ninety days' steaming. There were three watches of firemen and four of engineers. Taking the coal consumed per knot by the most economical officer as a standard of comparison with the others, the results gave a difference, respectively, of eight, twenty-two and thirty-odd per cent. That is, thirty per cent. more coal was consumed per knot made when one engineer was on duty than was consumed with another.

I mention the matter not as a specimen of poor engineering, but for the purpose of showing it to be possible to get rid of an excess of thirty per cent. of coal without generating the heat and steam due to its consumption. Seldom does it occur to the proprietor that his steam boiler has a direct passage from the furnace door to the smoke-stack, through which the heat from the furnace may pass and become fugitive without his having properly arrested its motion, or taken from it that to which he is entitled. Nor does he realize or know how little of the theoretical value of the coal it is possible for him to obtain under the best of conditions and with the most modern pattern of boiler skilfully fired. Ignorant of how little he could get under such circumstances, he little realizes how much he loses under the average practice. Still he continues to look for cheaper labor, and does not complain of larger coal bills.

The extravagant use of fuel is but *one* of the sources of loss occasioned by carelessness and ignorance, to be remedied, to a great extent, by the simple adoption of that form of pressure gauge that shall make a time record of its indications. That unobserved loss which comes gradually but with unerring certainty in the form of the impairment of the boiler's condition is, perhaps, of paramount importance to mere loss of fuel. One affects financial results solely, and the other deals directly with safety of life and property as well. Therefore, whatever unnecessarily injures or weakens a boiler should be avoided voluntarily, or, by legal enactment, prevented, as no one has the right to hazard either life or property; and the employment, wherever fluids are maintained under great compression, of an instrument which shall record upon paper what that compression is and has been, is not only scientifically expedient and useful, but becomes a manifest duty towards those who are in any way endangered thereby.

Since the discovery of the value of steam for a motive power, and for various other uses rendering steam boilers a necessity, no means

have heretofore been produced by which reliable records of the pressure to which such boilers were from time to time subjected could be obtained automatically, and to the very absence of which, in a great measure, are to be attributed the constantly recurring boiler explosions, with the usual verdict of "nobody to blame" when investigations are held. Without these records of the pressure carried, the fireman, who is frequently left in charge night as well as day, may take as much risk in carrying steam as suits his convenience or ignorance, regardless of economy and safety, and without fear of discovery. Before closing I wish to show you some stereopticon views, and the accompanying records of boiler pressure carried in the places severally named, and automatically written by means of Edson's time and pressure-recording steam gauges, are half-size reproductions from the originals.

Chart No. 40 is from the steamship Germanic, White Star Line. The fluctuations shown are attributable to the delays incidental to a steamer entering the port of New York.

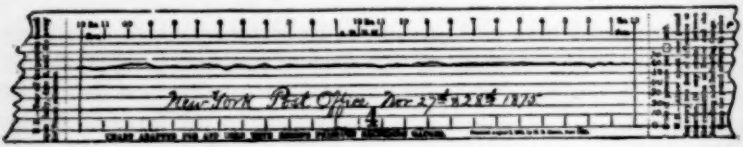


Chart No. 4, from the New York Post-Office, is a fair specimen of the regular manner in which steam can be maintained, notwithstanding the varied demands, as in this case, made upon it.

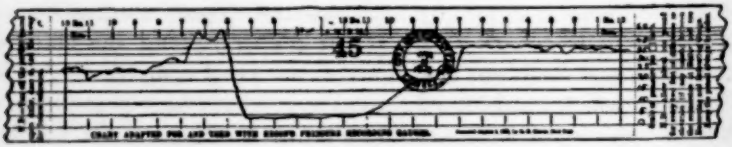


Chart No. 45 shows how a night fireman who was paid for keeping steam at 40 pounds all night succeeded, and unwarrantably strained the boiler twice before 7 A. M. to the extent of over 23 pounds above the point at which the safety (?) valve was supposed to have been set. This record led to the dis-

covery that the said safety valve had been overloaded to 80 pounds unknown to the Superintendent of Public Buildings, in whose charge the boilers were placed. These facts might never have been discovered and a disaster might have occurred, requiring experts and juries to solve the problem of a boiler bursting from over-pressure, with the so-called safety valve set at 40 pounds, while in fact the boiler sustained a suddenly accumulated pressure of over 60 pounds, as shown by the chart.

Chart No. 53 is from the Chelsea Paper Mill. The circumstances and conditions under which it was taken are not now known. It is reasonable to suppose, however, that with such extreme and sudden fluctuations of pressure, and of accompanying temperatures, the manipulation of materials used in the making of paper is very much affected, and the resulting products unsatisfactory. The boiler also, however well made, cannot long withstand the violence to which it is, in such a case, manifestly subjected.

Several of these charts show that steam can be, and is, carried, not only for hours, but days, with a nearly uniform strain upon the boiler; and where (as on ocean steamers) uniform speed is required and attained, other charts demonstrate clearly that ignorance, recklessness, or want of *thorough supervision*, renders the use of that valuable element uncertain in its results, and the generation thereof, in charge of improper persons, dangerous in practice.

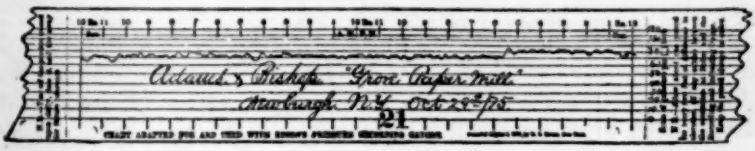


Chart No. 21 was taken in one of the paper mills of Messrs. Adams & Bishop. Mr. Adams is, perhaps, the oldest paper maker in this country. He has two of these recording gauges at work, and requires the charts to be sent from his mills in the country to his office in New York, daily, for his inspection.

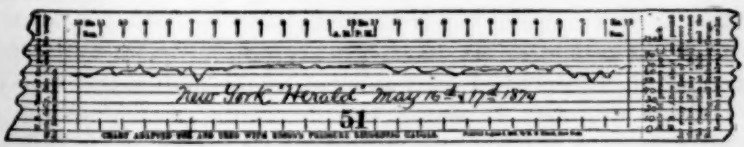


Chart No. 51 is from the New York *Herald*. Its former distinguished proprietor, the late James Gordon Bennett, was among the first to discern the

merits of this invention, and to apply it to practical use in his establishment. It enabled him, or his superintendent, to view at a glance the work performed in the engineer's department; and when disputes arose between the foreman of the press-room and the engineer, the charts were appealed to, and the engineer was generally triumphantly vindicated. The tracings shown demonstrate clearly that between 10.30 P. M. and 6.30 A. M. (while the morning edition was being printed) the pressure of the steam was kept very nearly at 70 pounds. The undulations in the lines during the other parts of the day were doubtless in consequence of the variety of work performed, as hoisting of material, etc., by elevators, occasional printing, and the application of steam for heating and other purposes.

Chart No. 43, from Morton's pen manufactory, New York, illustrates the delusion that thousands who use steam are under, when they assert that *they* "never carry steam at night," and that they "have a careful and competent fireman or (engineer), who economizes fuel," etc., etc. The chart shows that steam commenced falling at 5.15 P. M. At 6 P. M. the fires were banked for the night, there being no further use for steam until 7.30 the next morning; yet, from some unknown cause, the steam gradually accumulated after 9.30 P. M., and at 1 A. M. it had reached 66 pounds; from this time it remained at about the same pressure until 6.45 A. M., when the engineer came, cleaned his fire, and ran steam up to over 120 pounds by 7 o'clock, as shown by the chart. Comment upon so unnecessarily straining a boiler is not required.

The late eminent Chief of the Bureau of Steam Engineering, W. W. W. Wood, wrote as follows, in November, 1870: "I attach great importance to your recording gauges, by which *extravagance in use of fuel may be positively detected*, and accidents, which too frequently involve the loss of life and property, may be avoided." It hardly seems as though an intelligent man could say otherwise; but still they do exist.

In conclusion, does it not seem that our age is too far advanced in scientific improvements longer to permit boiler explosions and consequent loss of human life through negligence, ignorance and sordid notions of economy? I am warranted, by the indisputable records of charts for years, in saying that the Edson pressure-recording gauge writes a constant and unimpeachable record of the facts of variations of fluid pressure, and without which no steam boiler "plant" can be conducted either intelligently, economically, or safely;

that there is no longer excuse for mistakes or ignorance resulting in loss of life or property either on land or water, for, by the use of this pressure-recording gauge, the utmost immunity from danger, greatest economy in fuel, and the fullest information are obtainable. Surely such instruments are not only cheap in the end, but, where lives are in jeopardy, they are imperative and of moral obligation.

DISCUSSION.

Passed-Assistant Engineer W. F. WORTHINGTON, U. S. N.—*Mr. Chairman and Gentlemen:*—No one who has had charge of a marine engine will deny that a record of its performance is of great value. The first thing an engineer wants to know when coming on watch is how the machinery has been working, not only with regard to cool journals and smoothness of movement, but every detail of pressure, speed, amount of coal, etc., in order to know what requires his first care, and what his principal duty will be for the next four hours. If the record of the log as now kept—with only approximate accuracy—is of real value, it is evident that greater accuracy would increase its value. As long as the officer on watch can remain on the engine-room platform, and the steam pressure does not vary much, he can judge pretty well the average pressure for the hour; but let his attention be diverted for fifteen or twenty minutes, or longer, by a hot journal or a refractory feed pump, and the record of steam for that hour will not be worth much for scientific purposes. If the revolutions which are recorded automatically are the same, and also the vacuum, etc., he will probably assume that the average steam pressure was also the same; but this is at best a guess, and might be a wrong one, owing to a change in the direction or force of the wind which would allow the same number of revolutions to be made with less pressure. One of the most important uses of the recording gauge is to correct the error of observation due to the observer. I believe this error to be as much as two or three pounds. If this is cumulative—that is, if several observers come on watch in succession, each with a tendency to mark the pressure a little higher than it is—the steam may have been going down very gradually from neglected fires or change in quality of coal without the fact becoming apparent, until finally the speed of the ship is materially affected, and several hours are required to bring things back to their proper condition. The general tendency of the pressure, whether up or down, cannot be observed in so short a time as four hours. At the end of that time another observer comes on duty, and it is not known whether he records too high or too low, so that eight hours pass without affording a clue to the desired information; and this is sufficient time for the fires to get dirty if the coal is bad, or for the water-tender to run the water too high in all the boilers, so as to have time for a quiet smoke on the morning watch.

One of the first results of the introduction of recording gauges on shipboard would be more uniform firing, with all the well-known advantages to be derived therefrom. A diagram, such as is drawn by the Edson gauge, appeals

to the intelligence of the most untutored fireman, and there would be a friendly rivalry between the different watches to produce the best results, just as there now is to get the greatest number of revolutions recorded by the counter. Another advantage would be, that if one watch were weaker than another, the fact would become apparent by examining the diagrams for several days, and the men could then be rearranged to produce more even firing. Of course this can be done now, but not so well, owing to the doubt of the accuracy of the steam pressures recorded by different observers. Another advantage would be the greater accuracy in determining the mean I. H. P. for the day.

Up to the present time there is no reliable continuous steam-engine indicator, and it is necessary to average the steam pressure for twenty-four hours and then get an indicator diagram with the steam pressure, cut-off, etc., the same as the average shown on the log for the twenty-four hours. If the pressures recorded for each hour are not exact to several pounds, it may easily happen that the errors do not balance, but all lie on one side of the truth, and the mean I. H. P. would be deceptive.

Every one who has attempted to draw conclusions from the data recorded in the steam log, has felt the inconvenience which arises from the uncertainty with regard to the steam pressure. The vacuum, the revolutions, temperature of the feed, weight of coal, etc., can be ascertained with considerable accuracy or within fixed and comparatively narrow limits; but the steam fluctuates widely—as much as ten pounds when the working pressure is sixty—and therefore the conclusions drawn can only be relied upon as correct within these wide limits. It has frequently been observed that duplicate engines, the same in every detail, apparently, produce different I. H. P. A recording gauge, applied to each in turn, would soon determine if this difference was real, and thus advance us one good step towards the solution of an interesting and important problem. The engines of warships should be of the highest attainable efficiency, and, in order to make them so, it is necessary to know their defects. The best and, indeed, only way to discover these defects is to get accurate data of the working under every circumstance, especially at sea; and the way to get this data is to have it recorded automatically, because no one can devote his whole time to watching the various instruments. The only objection I ever heard to the use of a recording gauge was that it was unnecessary, because the officer on watch was trustworthy and it would not be right to set a machine to watch him. A complete answer to this objection is that one who does his work well does not care who knows it. One in charge of an engine has many other important duties besides watching the steam gauge, and the recording and alarm apparatus would materially assist him. The attachment for recording the number of revolutions simultaneously with the pressure is a valuable addition to the Edson gauge. The pressure and revolutions often vary independently of each other, and when the latter vary—a fact at once detected by a practical ear before any of the other instruments note it—then the cause could immediately be inquired into and the remedy applied. Although, in time of peace, every run made by a war vessel should be a trial trip in one sense, the value of the recording gauge would appear highest when a full-power trial is made. On such occasions the danger of hot journals, breakages, etc., is greatest, and every one on duty is

fully occupied in causing the machinery to do its utmost, so that just when there is most need of getting correct data there is least time to collect it.

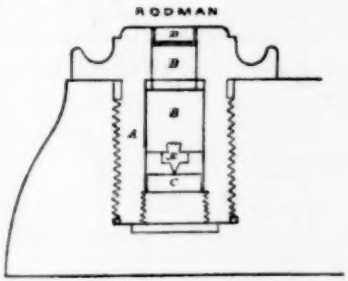
Lieutenant A. M. KNIGHT, U. S. N.—*Mr. Chairman and Gentlemen:*—I have been requested, in connection with the subject of the evening, to give a description of the pressure-recording instruments used in the experimental firing of great guns.

The difficulty in measuring the pressure developed by a powder charge burning in the bore of a gun arises from: 1st. The magnitude of the pressure involved; 2d. The suddenness with which it is developed; 3d. The brevity of the time through which it acts; 4th. The rapidity with which it varies during that time, under the influence of conditions of temperature, motion, etc., of which we have but a very limited knowledge.

The magnitude of the pressure involved, which commonly varies from twelve to twenty tons to the square inch, and in exceptional cases rises to twenty-five and even thirty tons, would of itself put out of the question the employment of any ordinary gauge. Various instruments have been invented which meet this and the other sources of difficulty enumerated above with more or less success. Of these, those which are in practical use at the present time may be divided into two general classes: 1st. Those in which the pressure is measured by opposing to it a known high resistance—usually the resistance of a ductile metal like lead or copper to deformation by cutting or crushing—and 2d. Those in which the pressure is measured by its effect in imparting velocity to a body of known dimensions and mass.

Of the first class, the most important examples are the Rodman, the Woodbridge and the crusher gauges, and the Deprez manometric balance. To the second class belong the Noble chronoscope, the Sébert velocimetre and the Sébert self-registering projectile.

The Rodman gauge (Fig. 1) was invented about 1857 by Colonel Rodman, of the United States Army, and embodies the general principles of the more recent Woodbridge and crusher gauges.

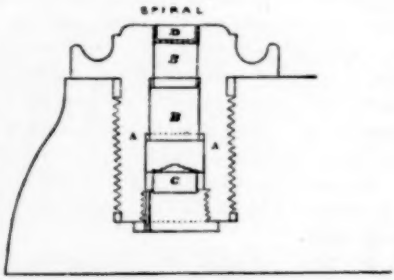


It consists of a steel cylinder, *A*, which screws into the wall of the gun or into a plug inserted in the powder chamber, its head being flush, or nearly flush, with the surface of the bore. Within the cylinder is fitted a piston, *B*, one end of which, when the gauge is in place, is just inside the head of the

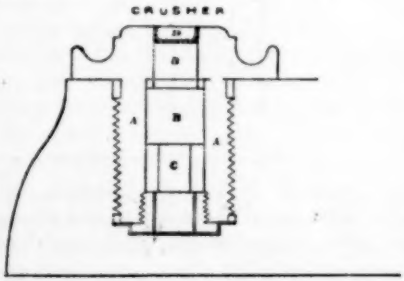
gauge and free to be acted upon by the gases developed in the bore on firing. To the other end of the piston is attached a knife-edge, *E*, of tempered steel, and in light contact with this is placed a disc of copper, *C*, resting upon the screw plug which closes the base of the cylinder.

A copper cup, *D*, placed over the head of the piston, acts as a check to prevent the gases from entering the gauge.

When a pressure is developed in the bore of the gun, the piston of the gauge is forced inward, and the knife-edge enters the copper disc to a depth dependent upon the amount of the pressure. The gauge is then removed from the gun, the disc taken out, and the dimensions of the cut measured and compared with those of cuts made upon the same or similar discs by the same knife-edge and piston when subjected to known pressure in a testing machine. It is assumed that equal pressure in the machine and in the gun will produce equal effects upon the copper discs. As will be explained later, this assumption involves an error.



The Woodbridge gauge differs from the Rodman in the cutter employed. The knife-edge of the Rodman system is replaced by a narrow groove, with a cutting edge, running spirally around a concave conical surface on the end of the piston. The outer rim of this surface is in contact with the circumference of the copper disc when the gauge is ready for use. As the piston is forced in upon the disc by the pressure of discharge, the disc is compressed from its circumference towards its centre, the amount of compression being indicated by the length of the spiral cutting edge, which leaves its mark upon the disc. This record is compared with that made upon similar discs by the same piston acting under known forces.



In the crusher gauge, the cutters of the two preceding systems are discarded. The piston head is plain, and between it and the base plug of the gauge is placed a copper cylinder whose length is accurately measured before and after firing. The amount by which it is found to have been shortened measures the pressure to which it has been subjected—a comparison being made as in the Rodman and Woodbridge gauges, with the effect produced by known pressure applied in a testing machine.

The Rodman gauge is used in official experiments in Germany, Russia and Italy. The crusher is used in France and England, and both the crusher and Woodbridge are used in this country.

In ordinary work, chamber pressures only are recorded. For these the gauge is inserted in the face of the mushroom or breech block, or, with a muzzle-loading gun, in a plug fitted to the rear of the powder chamber.

In special experiments, gauges are frequently used in the walls of the gun along the sides of the chamber and the bore.

They are sometimes also screwed into the base of the projectile, but here their record is modified by the motion of the projectile, and to an extent varying with every change in the amount or kind of the powder used.

The following sources of inaccuracy are inherent to all systems relying upon the deformation of metals for the measure of a pressure acting under the conditions which obtain in the bore of a gun:

First. There is a wide difference between the effect which a given pressure will produce when applied more or less slowly, as in a testing machine, and that which the same pressure will produce if applied suddenly, as in the explosion of confined gunpowder.

If in the testing machine the force were applied very gradually, and if in the gun the gases were evolved instantaneously, the ratio between the effects produced would be as two to one—the effect in the gun being two. This extreme case is far from existing, both because, by appropriate arrangements, the action of the machine may be made very sudden, and because the development of the maximum pressure of the powder gas is not instantaneous. Nevertheless, there undoubtedly does exist a difference which, whether large or small, tends to make the indications of the gauge higher than the pressure which has actually existed in the gun.

It should be noted, however, that the pressure is exerted upon the walls of the chamber exactly as it is felt by a pressure gauge in the chamber, so that the real strain upon the gun is that which is shown by the gauge, and not that which would be deduced from a theoretical consideration of the tension of the gases.

Second. In the deformation of a metal, whether by cutting or crushing, the element of time necessarily enters. Up to a certain point the effect will increase with the time.

In a testing machine, the force applied has time to produce its full effect; in a gun the pressure is relieved as suddenly as it is developed. It is not possible to estimate very accurately the time through which the maximum pressure acts, but it probably does not exceed, with the slowest powder, the one-thousandth part of a second.

This consideration would lead to the conclusion that the pressures recorded, when interpreted by comparison with the work of a testing machine, are too low. This source of error and the preceding one, then, tend in opposite directions, and to a certain extent offset each other. They would both be reduced to zero if, at the instant when the pressure is at a maximum, it and the force opposed to it by the resistance of the copper discs to deformation were in perfect equilibrium. Such a condition is approached by the device, commonly resorted to in practice, of subjecting the discs which are to be used in experiment to a preliminary pressure slightly lower than that which is anticipated from the firing.

This reduces, but does not remove, the difficulty. Of the error remaining, that part due to the suddenness with which the pressure is applied will be much greater with gauges placed in the path of the projectile forward of the force band than with any others. These are suddenly unmasked by the motion of the projectile to a pressure already developed, which thus comes upon them with the full force of a blow, so that the pressure which they record is doubtless considerably above the tension actually existing. Thus, of two gauges separated from each other by a few inches, but of which one stands in rear of the force band and the other in front of it, the second may give a record several tons higher than that of the first. That this is not a point of theoretical importance only has been abundantly shown in several foreign experiments, notably in those of the English Ordnance Committee of 1875, and more recently in those of Russian officers at Aboukhoff, and of French officers at Gavres. In all of these cases the crusher gauges half a calibre forward of the force band read from twenty per cent. to forty per cent. higher than those in the chamber. With regard to the bearing of these facts upon the strength of guns, it should be considered that, so long as the surface of the bore is continuous, the pressure will be communicated by the elasticity of the metal somewhat in advance of the force band, and no point will receive a sudden blow. At any break, however, which may occur at the continuity of the bore—as, for instance, where the two parts of a tube butt together—there will be an interruption of the transmission of pressure in front of the band. No strain will be felt by that part of the tube forward of the break until the force band has passed it, when the full pressure of the gas will come upon it with a blow, exactly as it would come upon a pressure gauge at that point; and the strain tending to rupture the gun will be just double what it would be if the fibres of the bore were continuous.

This would seem to be a point of weakness in those systems of gun construction in which the tube is composed of two lengths, or in which a liner is inserted which does not extend to the muzzle. It would seem also to furnish an additional reason for the use of a highly elastic steel.

The Deprez manometric balance resembles the instruments already described in opposing a known resistance to the work of the powder gases, but differs from them in the nature of the resistance.

It consists of a piston with a large and a small head connected by a stem running through the wall of the gun. The small head stands flush with the face of the bore, and is acted upon like the piston heads of the gauges already

described, by the gases in the gun. The large head is outside the gun and is enclosed by an air chamber, in which it is placed under a known pressure of air. The ratio between the areas of the piston heads is 1 to 400.

Before the gun is fired, the air pressure holds the larger piston head firmly down, binding a small strip of metal between its lower face and a flat plate which forms part of the gauge. A powerful spring attached to the metal strip seeks to draw it out, but can start it only on condition that the piston of the gauge is lifted. If, when the gun is fired, the pressure developed in the bore and exerted upon the small head of the piston exceeds that of the air upon the larger head, the piston will be lifted and the metal strip released. Knowing, then, in any case, the pressure of the air, we can tell of the pressure in the bore, not what it has been, but whether it has or has not exceeded a certain known amount.

By repeating the experiment with constant conditions of powder, projectile, etc., but with varying pressure in the air chamber, it is possible to arrive at a close approximation to the pressure in the bore. It should be added that by an electrical attachment the starting of the metal strip is registered automatically, and that in practice a number of gauges with different pressures are used in a single experiment.

Of instruments which measure pressure by work done in imparting motion, the most important are the Noble chronoscope, the Sébert velocimetre, and the Sébert self-registering projectile.

The Noble chronoscope was used, in connection with crusher gauges, by the English Ordnance Committee which, between 1875 and 1877, conducted a series of experiments upon the action of fired gunpowder. It records the velocity of the projectile at successive intervals of its path in the bore, from which the accelerations, and hence the pressures corresponding, can be deduced. A number of plugs are inserted in the wall of the gun at points forward of the base of the projectile, each plug carrying a small wire which forms part of an electric circuit communicating with a delicate time-recording instrument or chronoscope. When the plugs are in place in the gun, their inner ends, carrying the wires which, as already explained, are in circuit with the recording instrument, stand just inside the bore. The wires are cut in succession by the projectile as it passes through the bore, each circuit, as it is broken, leaving a record upon the cylinder of the chronoscope.

The distances between the plugs being known, and the interval of time between the cutting of any two, the velocity between those two is known, and the pressure acting to produce the successive accelerations can be deduced.

In the Sébert velocimetre the acceleration in velocity of recoil of the gun at a given instant is made the measure of the pressure acting in the bore at that instant.

A ribbon of flexible metal, thinly coated with lampblack, is attached to the gun and moves with it. Above the ribbon stands a tuning-fork, suspended between two electro-magnets. A small spring attached to and vibrating with the tuning-fork makes and breaks the circuits of the electro-magnets so that

the latter are magnetized and demagnetized very rapidly, and the tuning-fork is attracted alternately to one side and the other. Thus, after a single instant of initial vibration given to the fork, its motion is controlled by the electro-magnets, and will remain constant as long as the strength of the magnets remains constant.

To one of the branches of the tuning-fork is attached a small pencil, held in light contact with the blackened surface of the flexible ribbon. If the fork be started vibrating while the ribbon is at rest, the pencil will trace a line at right angles to the length of the ribbon. As the gun starts to the rear upon firing, the ribbon is drawn out under the tuning-fork and the line traced by the pencil becomes sinuous. From its direction at any given point, knowing the velocity of vibration of the fork, we can determine the velocity of recoil corresponding to that point. From velocities at successive points are deduced accelerations between those points, and from these are derived the pressures acting in the bore; provided that we have an accurate knowledge not only of the mass of the gun and carriage, but also of the resistance acting in opposition to the recoil.

The Sébert self-registering projectile is a hollow shell, through the centre of which runs a steel rod, square in section, and covered on one of its four sides with a coating of lampblack.

Loosely attached to this rod, and sliding freely upon it, is a block of metal carrying a tuning-fork, to one of the branches of which is fitted a pencil, held lightly in contact with the blackened face of the square rod.

In preparing the projectile for firing, the sliding block is brought to the forward end of the rod, and the branches of the tuning-fork are spread and held apart by a small lug on the rod. Thus prepared, the projectile is placed in the gun like an ordinary shell, and the gun fired. As the projectile starts forward, the sliding block, to which the tuning-fork is fixed, by virtue of its inertia remains at rest, the stem on which it moves sliding through it. At the first instant of motion the lug is withdrawn from between the branches of the tuning-fork, and the latter begins to vibrate at right angles to the direction of the blackened rod, which is slipping past it with the velocity of translation of the projectile. The pencil fixed to the fork thus traces a sinuous line upon the surface of the rod, the direction of which, at any given point, shows the ratio between the velocity of translation of the projectile and the velocity of vibration of the tuning-fork at that point.

It is assumed that friction between the rod and the sliding block is entirely overcome, as practically it is, so that the length of the central rod which has passed the pencil at any given instant is equal to the distance which the projectile has moved up to that instant. From the accelerations indicated by the increase in velocity, the pressures acting on the base of the projectile are deduced—neglecting that part of the work done which is absorbed in friction in the bore and in imparting rotation to the projectile.

As the length of the rod on which the record is made is limited by the length of the projectile, this method can give only the pressures corresponding to the motion of the projectile through something less than its own length. This difficulty has been overcome by a modification of the method in which a second

block is set in motion at the forward end of the rod when the first block reaches the base of the projectile.

In the early part of this paper it was stated of the three gauges whose indications depend upon the deformation of metals, that they were subject to sources of error which were reduced, but not entirely removed, by certain precautions commonly taken in practice. It will be interesting, before closing, to inquire how far these errors probably impair the accuracy of results based upon the indications of such gauges; the more so as crusher gauges placed in the powder chamber have been used in the tests of the new Navy guns and powder.

It is sometimes stated that while the indications of such gauges are reliable for *comparisons* of pressure, they are not to be trusted for absolute values.

This subject has been very elaborately investigated by the eminent French artillerist and mathematician, Monsieur E. Sarrau, who concludes, as the result of his experiments, that the indications of crusher gauges in the powder chamber are practically correct, not only comparatively but absolutely, the errors due to the manner in which the pressure is applied being within the limits of accuracy of the instrument.

With gauges forward of the band slope the case is quite different, and here he concludes that the indications of the gauges are much too high, and altogether unreliable for ballistic calculations.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

ON THE STUDY OF NAVAL HISTORY.*

(GRAND TACTICS.)

By Rear-Admiral S. B. Luce, U. S. N.

INTRODUCTORY.

The term "Naval Tactics" has been used in such a general way as to lead to some confusion of ideas regarding its true meaning. Some writers restrict it to the evolutionary movements of a fleet, and such as are to be found in the Tactical Signal Book; others limit it to the manner of conducting a fleet in battle; while others again use the term in both senses, and often in such a careless way as to lead themselves and their readers into no little confusion. It is just as well that we should, in the very beginning, fully understand an expression which promises to be of frequent use.

Tactics has been well defined as the art of military movements. Naval Tactics is the art of conducting *the military movements of a fleet.* Battle being the chief object and end of a fleet, the order of battle constitutes the principal formation; and to bring the vessels composing a fleet, from any given order, to the order of battle, or any other order, is to perform an evolutionary or tactical movement. There are, besides the order of battle, various other orders and movements—such as chasing an enemy's fleet; escaping from a superior force; protecting a convoy; navigating the high seas; anchoring; going in or out of port, etc., etc.

These several orders, or formations, formerly called the "orders of sailing," etc., etc., were laid down in the Signal Book; and the methods of changing from one order to another were fully prescribed, a diagram accompanying each evolutionary signal number, showing the positions and movements of each individual ship. Thus, when, in 1790, Admiral Lord Howe rearranged the Signal Book of the

* Read at the Naval War College, September, 1886.

English Navy, he introduced "instructions for the conduct of the fleet in the execution of the principal evolutions which were illustrated by figures." These evolutions may be termed Elementary or Minor Tactics. In thus revising the Signal Book, Lord Howe rendered a great service to the English Navy, and the value of his work was generously acknowledged by Nelson. In his letter to Earl Howe of January 8, 1799, giving some account of the battle of the Nile, Nelson writes: "This plan" (of battle) "my friends" (the captains of the several ships composing the fleet) "readily conceived by the signals, for which we are principally, if not entirely, indebted to Your Lordship. . . . ." Later on in the same letter he speaks of Earl Howe as "our great master in naval tactics and bravery." The term "naval tactics," as here used by Nelson, is undoubtedly to be taken in connection with the revised Code of Signals, and refers to the Manual of Fleet Evolutions, which had been rearranged by Howe. Howe not only revised and greatly improved the Signal Book of the English Navy, including the Code of Tactical Signals, but he enjoyed the reputation of being indefatigable in the exercising of the fleet under his command in tactical evolutions, and the transmitting of orders by signals. He was, moreover, very exacting, requiring great precision in the execution of all manœuvres. But this seems to be the limit of Howe's claim to be considered a tactician. He was skillful in Minor Tactics.

While Nelson was giving credit to Howe for a code of Minor Tactics, he, himself, was developing a system of Fighting Tactics (as it was formerly termed) till then little known in the English Navy. It was a system based upon sound military principles: that of beating the enemy in detail. In the letter just quoted, Nelson gives the gist of his plan of attack at the Nile. He says: "By attacking the enemy's van and centre, the wind blowing along their line, I was enabled to throw what force I pleased on a few ships." And it is this idea of placing two ships on one of the enemy, of doubling on him, that constitutes the merit of Nelson's fighting tactics.

Here, then, we have two celebrated tacticians. First, Howe, constantly exercising the fleet in Minor or Elementary Tactics, and preparing a school of officers who were subsequently to second Nelson in the development of the higher school of Grand Tactics; and, secondly, Nelson, who may be said to have founded a school of Grand Tactics. For it should be remembered that in Howe's great battle of the first of June (1794), he exhibited no such fighting

tactics as was afterwards practised by Nelson. With his accustomed exactness he formed his line with great precision, and stood down for the French fleet, each ship steering for her opposite, with the intention that all should pass through and haul to the wind, to leeward of the French line. There is no hint of crushing any one part of the enemy's force by overwhelming numbers; no indication of an intention of doubling on the van, or centre, or of placing the enemy between two fires. It was simply the old custom of placing ship against ship, and allowing a great fleet fight to resolve itself into a series of single engagements. The result was the customary indecisive battle, and consequent popular dissatisfaction. Howe, then, was not a tactician in the sense that Nelson was.

These two distinguished officers therefore represent the two different branches: the first Minor, Elementary, or Evolutionary Tactics; the second Fighting or Grand Tactics, or the Tactics of Battle. These two branches, so inseparably connected, and which together with Strategy form one science, should, for the purpose of our present studies, be held separate and distinct. Nelson was also a great strategist; but this again is a distinct branch, which will be considered further on. At present we have to do with Grand Tactics alone—that is to say, with Fleet Fighting and its history.

The Signal Book furnishes, as already observed, the necessary instruction in the evolutions of a fleet. But there is no recognized code of Grand Tactics. In the early days of sailing tactics the navies of England and France had their Fighting Instructions, the latter contained in the Ordonnance du Roi. But it is quite safe to say that no navy of the present day can claim what may be called a satisfactory system of Fighting Instructions; or, we might go so far as to say, a satisfactory fleet organization. It is in the hope of obtaining clear ideas of the latter, so as to enable us to organize a fleet on sound principles, that one part of our studies is to be directed. Another essential part is to study the great sea fights of history, that we may form clear conceptions of how to fight the fleet we have organized. This is our present business.

The plan of attack drawn up by Nelson during his pursuit of the French fleet to the West Indies contains the general principles which guided him in all his battles; principles which are in perfect harmony with the Science of War, and just as applicable now as they were then. In his memoranda he begins by enunciating the broad principle that it is the business of a commander-in-chief "to bring

an enemy's fleet to battle on the most advantageous terms." One of these advantages he states to be "close action"; in other words, that the enemy is to be brought within effective range of his guns. He next assumes that the admirals and captains of the fleet will thoroughly understand his plan of battle; and, therefore, that few signals will be necessary.

This last expression has been, we may here remark parenthetically, misapplied and misunderstood.

Nelson closed the Signal Book because, having made his dispositions with great care beforehand, and fully instructed his captains as to his plan of battle, signals were no longer necessary. Battle once joined, every one was trusted to carry out his allotted part of the general plan.

Howe closed the Signal Book because he had no plan of battle beyond the simple method of the barbarian, to pit ship against ship.

It is easy to understand, therefore, how, when the opponents were fairly matched in military force, the results could be decisive in the former case and indecisive in the latter.

Having defined and illustrated the two branches of Naval Tactics, let us now take a cursory view of its history.

In the ardor of pursuit of a new study, such as we have declared "Naval Warfare under Steam" to be, we must not be unmindful of the lessons of the past. "History," it has been well said, "is Philosophy teaching by example." We may add that history admonishes by its warnings. It is by the knowledge derived from the history of naval battles that we will be enabled to establish a number of facts on which to generalize and formulate those principles which are to constitute the groundwork of our new science.

"History, as a means of instruction in the art of war, is obviously of the highest value," observes one military writer. "But," he adds, "to make the study of history profitable, the mind ought, in the first instance, to be prepared so as rightly to distinguish between military events which may be analyzed and reasoned upon with advantage, and those which may be regarded merely as events in the world's history destitute of any important bearing on the art of war." It is only by a philosophical study of military and naval history that we can discover those truths upon which we are to generalize. "Thus," as the writer just quoted states, "the victory at Wagram has been

traced to the same primary cause by which the battles of Cannæ and Pharsalia were gained, and the existence of fundamental principles, by which all the operations of war should be conducted, has been placed beyond doubt by the researches of Jomini and other military writers." What has been done for military science is yet to be done for naval science. In the pride of an advanced civilization, we are too apt to look with contempt upon the old sailing tactics, and the battles fought under them. But even in these days of steam and electricity we may study with advantage the works not only of John Clerk and Paul Hoste, but of Thucydides and Herodotus.

Minor Tactics change with the change of arms or improvements in naval architecture.

Not so with Grand Tactics. But whether it was Phormio or Agrippa or Russell, a Nelson or a Perry, the victory has generally been with that leader who had the skill to throw two or more of his own ships upon one of the enemy. That is one of the most valuable lessons of all naval history, and that, it may be stated here, is one of the fundamental principles of our science. It is the capacity to carry out that principle that gives evidence of the skillful tactician. It is the ignoring of that principle that serves as one of the most impressive warnings of naval history.

Strategy is still less affected by the mutations of time and the advance of learning. Alexander the Great found it impracticable to reduce Tyre without the aid of a fleet. On the appearance of the Cyprian and Phœnician war galleys, the Tyrians called in their own vessels and sunk triremes in the channel ways to block the entrance to their harbors. Twenty-two centuries later the combined fleets of England and France, co-operating with the armies on shore, compelled the Russians to resort to the same expedient; that is, to close the harbor of Sebastopol by sinking vessels of war in the entrance. The Persian invasion of Greece taught the Athenians the necessity of having a navy. A navy was built, and at Salamis proved the salvation of the State.

England taught the United States the same lesson. Great strategic combinations it was found could not be formed without a navy; a navy was created—a navy small in numbers, but great in spirit—and the victories on Lake Erie and Lake Champlain proved its inestimable value. History is full of such parallels. The invasion of Britain was once rendered possible by reason of the strength of the Roman fleet. But from the time of the Invincible Armada to the day of Trafalgar

it has been impossible through the constancy and devotion of the English Channel Fleet. And although there have been such radical changes in the means of carrying on naval warfare, yet the same strategy which enticed Nelson to the West Indies in the vain pursuit of the French Fleet might be practised again to-day.

There are certain general principles which are just as applicable to the management of a sea army of the nineteenth century as they were in the days of Salamis or Actium, of Trafalgar or Lake Erie. Hence, it may be stated in general terms that, while the principles of the Science of War remain unchanged, the rules of the Art of War vary with the implements of war.

The introduction of the rules of the military art into the conduct of a fleet, and the revival of the spur, the rostrum of the galley period, has not only brought us back to the same general system of tactics in use during the ancient civilization, but has rendered a quasi-military education indispensable to the naval officer.

The great captains who achieved success at the head of the armies of Greece and of Rome, carried with them their fighting tactics to the fleet, and on the decks of their galleys won the *corona navalis* for victories due to their military skill.*

It was so in the Middle Ages. King Edward III., who was distinguished for his military abilities, defeated the French in the great battle of Sluys—a battle which, for the skillful manner in which it was fought, was thought worthy to be compared to the masterpieces of the ancient Athenian navy.

It was so at the dawn of modern civilization. Don John of Austria, who was essentially a soldier, gained at Lepanto one of the greatest naval battles of history.

It was so during the earlier period of English naval history. Blake, Monk, Popham, Deane, Prince Rupert and the Duke of York, all of whom held the highest commands during those terrible contests with the Dutch for the mastery of the narrow seas, were all men of military training. It was absolutely necessary, indeed, that men of military capacity should control the military movements of those large fleets on which the very existence of England depended, for the naval officer of that day knew little beyond the mere rudiments of his calling as a seaman.

*In Vol. III., No. 1 (April 20, 1876), of the Record of the U. S. Naval Institute, an attempt was made to show more in detail than is now necessary the formation common to the fleets and armies of the Oar Period.

As the navy of England developed into a distinct profession, the officers were sent to sea at a very early age and kept actively engaged, that they might become inured to the hardships and privations of ship life. With many undoubted advantages, the custom was open to certain objections. While it made them good, practical seamen, it gave them the sailor's proverbial distaste for acquiring knowledge through the medium of books. Thus they came to excel in all the practical details of their profession, but they knew little of the theory, or general principles, on which the science of that profession was based. To handle a ship in a seamanlike manner, and to preserve one's station in the fleet, seems to have been the highest point to which the practical education of that day aspired. True, that was much—indeed, it was a great deal; the value of that instruction was scarcely to be overestimated. When we consider the size of the fleets; their protracted cruises; their long and tedious blockades through all the changes of seasons; the vicissitudes of weather, and the very poor sailing qualities of many or most of the ships before copper sheathing came into use, we cannot withhold our wonder and admiration for the skill, the devotion and courage of the English naval officers during those long naval wars which fill so large a space in the English history. But that severe school of practice, thorough as it undoubtedly was, proved wholly insufficient. The constant employment of the officers at sea, and the absence of a higher school, were an effectual bar to their acquiring even the rudiments of the military art. Generation after generation of English naval officers passed without the slightest attempt at methodical instruction in naval tactics. Such knowledge of the art as was acquired must have been by the process of absorption through observing the evolutions of the fleet and the manœuvres of one's own ship. The Signal Book was the only manual of evolutions; and that was sedulously guarded from the eyes of the profane. For fear it might fall into the hands of the enemy, as it did on one or two notable occasions, or be surreptitiously copied by traitorous hands, it was heavily weighted with lead; and, when not in actual use, kept within the sacred precincts of the captain's cabin, whence none but the elect might take it. In the event of defeat it was to be cast into the sea. Furthermore, the flag officers of the English Navy were, for over a century, heavily handicapped by the Fighting Instructions of 1665, which prescribed certain rules for the conduct of a fleet in battle—rules which proved to be not of general application, and not always in harmony with the prin-

ciples of war. Unfortunately, these rules, insufficient as they were, received full confirmation by the mature judgment of two courts-martial which may be numbered among the *causes célèbres* of the English Navy. The first was that of Admiral Thomas Mathews for his failure in the engagement with the Franco-Spanish fleet off Toulon in the spring of 1744. The second was the trial of Admiral John Byng for his failure in the battle with the French fleet off Minorca in May, 1756.

The Instructions, on which, in a great measure, the judgment of the court in each case turned, were drawn up by the Duke of York (James II.) in 1665. (See "Fleets of the World," No. 1, Vol. III., of Record of U. S. Naval Institute, before alluded to.)

This was during those severe contests with the Dutch for the mastery of the narrow seas in which the conflicts took place. The line of battle, which was then for the first time observed according to Paul Hoste, though certain authors maintain that it was known previously by the Dutch, consisted of the close-hauled line ahead, in practice seven points from the wind. Owing to the limited sea room and the dangerous coasts, the weather gauge was of the very first importance, and as a consequence it was necessary to preserve the order of battle with some degree of precision. When the field of operations was transferred to the broad ocean these conditions became greatly modified; yet, notwithstanding this, the Instructions continued to be binding, and were blindly observed to the frequent discomfiture of the English Navy. Thus, in Mathews' fight off Toulon, his vice-admiral, Lestock, accused him of "rashness and precipitation in engaging the enemy before the line of battle was formed, contrary to the rules of war and the *practice of our best admirals;* therefore the sole miscarriage was chargeable on the admiral, who, by his imprudence in fighting, at first, at such a disadvantage, had endangered the whole fleet; and after, by a quite contrary conduct, suffered the enemy to escape."

Mathews, though he had exhibited the highest gallantry, was found guilty and declared to be "incapable of holding any further employment in His Majesty's service."

Byng, on the other hand, failed from a too strict observance of the line of battle. Warned by the result of the former court-martial, he declared at the commencement of the battle that he "would not fall into that error with which Mr. Mathews was charged, and which proved his ruin," that of engaging the enemy before his line of battle

was formed. He was found guilty of the charges brought against him and condemned to death. He was said to have been "too great an observer of forms, of ancient rules of discipline and naval etiquette."

During the Dutch wars the opposing fleets were no sooner out of port than they sighted each other; nor was it likely that the men who destroyed the shipping in the Thames, and whose guns were heard in London, would waste much time in manœuvring. Battle was joined with eagerness on both sides, and the fighting was of the most stubborn character. But on the broad Atlantic, or even in the Mediterranean, fleets might cruise week after week without falling in with each other. When they did the English instinctively manœuvred, as they had done in the Channel, for a windward position, which the French, committed to a different policy, and hampered by no such traditions, readily yielded. If the two fleets were on the same tack, and on parallel lines, the French would reduce sail, and under easy canvas await the enemy. If he came up astern, the van division of the English would first engage the rear of the French. The English could not use the lower-deck batteries in a fresh breeze, while the French, using their weather guns, could get all the elevation they needed. Firing high, they cut away the spars, rigging and sail of the English, which reduced their speed and threw the head of the line into confusion. Or, if the distance between the two lines was beyond the range of their guns, the English would stand on till the leading ships were abreast of each other, when they would run down to engage, each ship selecting her antagonist. But while they were standing down for the French, the latter would keep up a constant fire, raking their enemies as they approached; the English, meanwhile, unable to bring but a few bow guns to bear. When the English "brought by the wind," so as to use their broadsides, the French would bear up, make sail, and, running to leeward, reform their line and await another attack; this, the English, by being cut up by the French fire, were seldom able to make. Or, the two fleets might cross on opposite tacks, firing distant broadsides in passing. Again, the French Government had early submitted the various problems which enter into shipbuilding to rigid mathematical discussion at the hands of their most eminent mathematicians. The French ships, therefore, were superior to the English in the essential quality of speed, and the French naval authorities had recognized at the very first the necessity of sheathing their ships with metal. For

these reasons the French admirals found no difficulty in avoiding a battle when it did not suit their purpose to fight; and, as the resources of their country did not enable them to build and fit out ships with the rapidity with which it could be done in England, it was their policy to avoid decisive actions unless the chances were greatly in their favor; hence, it frequently occurred that they declined to bring on a general engagement.

The many indecisive battles which resulted from these several causes gave great dissatisfaction in England, and finally culminated in the court-martial of Admiral Keppel for his failure in the battle off Ushant in 1778.

As in the case of Mathews, the charges were brought by his vice-admiral (Sir Hugh Palliser), the second in command, and mainly for the same reason. The first charge declared in effect "that on the morning of the 27th of July, 1778, having a fleet of thirty ships of the line under his command, and being in the presence of a French fleet of a like number of ships of the line, the said admiral (Keppel) did not put his fleet in the line of battle, or into any order proper for receiving or attacking an enemy; but, on the contrary, by making signal for several ships to chase, increased the disorder of his fleet, and whilst in the disorder he advanced to the enemy and made signal for battle, the enemy's fleet being formed in a regular line of battle on that tack which approached the British fleet. By this unofficer-like conduct a general engagement was not brought about," etc., etc.

A brief abstract from Admiral Keppel's defense will show the line of his argument: "On my first discovering the French fleet at 1 P.M., July 23d, I made signal to form the order of battle, which being effected towards evening, the fleet was 'brought to' till morning, when, perceiving the French had gained the wind during the night, and carried a pressed sail to preserve it, I discontinued the signal for the time and made signal to chase to windward. If, by obstinately adhering to the line of battle, I had suffered the French to have separated from me; if the expected convoys had been cut off, or the coast of England had been insulted, what would have been my situation? Supported by the examples of Admiral Russel and other great naval commanders, who in similar situations had ever made strict order give way to reasonable enterprise, and particularly of Lord Hawke, who, rejecting all rules and forms, grasped at victory by an irregular attack,* I determined not to lose sight of the French fleet by being

*Alluding, no doubt, to the battle of Quiberon in 1759.

outsailed, from preserving the line of battle," etc., etc. The court found the charges malicious and ill-founded.

In his official report of the battle the admiral had said: "The object of the French seemed to be the disabling of the King's ships in their masts and sails, in which they so far succeeded as to prevent many of the ships of my fleet being able to follow me, when I wore to stand after the French fleet. They took advantage of the night and made off. The wind and weather being such that they could reach their own shores before there was any chance of the King's fleet getting up with them, the state the ships were in—in their masts, yards and sails—left me no choice of what was proper and advisable to do." That was to return to Plymouth. The opinion of D'Orvilliers, the French admiral who had been opposed to Keppel, is valuable: "During the fight," said he, "the English had the advantage, but after the firing ceased I out-manoeuvred Mr. Keppel."

The insignificant result of the battle and the court-martial which followed created great interest in England. But of the flood of literature that was poured upon the subject, the only publication that concerns us now is the pamphlet printed for private circulation by the Scotch country gentleman named John Clerk.* Up to his time there had been so many great battles the results of which were wholly out of proportion to the numbers engaged, that Clerk was led to believe the French "had discovered some new system of tactics; and that the English practice, since it was always unsuccessful, must have been radically wrong."

In his more elaborate treatise, which appeared in 1790, he states that "after an examination of the late engagements it will be found that the French have never shown a willingness to risk making an attack, but have invariably made a choice of the leeward position; and when extended in line of battle they have disabled the English fleets in coming down to the attack. Upon seeing the English fleet disabled, they have made sail and demolished the van in passing, and upon feeling the effect of the English fire they have withdrawn, at pleasure, either a part or the whole of their fleet, and formed a new line of battle to leeward. The French have repeatedly done this. It will be found, on the other hand, that the English, from an irresist-

* See "Life of John Clerk" by the eminent Scotch professor, Playfair. Clerk seems to have had a natural capacity for military affairs. Disappointed in his early hopes of entering the Navy, he gave much time to the study of Naval Tactics.

ible desire of making the attack, have as constantly courted the windward position, and have repeatedly had their ships so disabled, by making the attack, that they have not once been able to bring them to close with, to follow up, or even to detain, one ship of the enemy. Therefore there was every reason to believe that the French had adopted and put in execution some system which the English either had not discovered, or had not yet profited by the discovery."

To illustrate his position he cites a number of cases, such as Byng's unfortunate action, already referred to; Pocock's battles with M. D'Aché in the East Indies in 1757; Admiral Byron's engagement off Granada in 1779; Arbuthnot's off the Capes of Virginia in 1781, and that of Graves about the same time and place. The last instance in the series is Lord Rodney's engagement off Martinique, April 17, 1780: "Notwithstanding the personal gallantry of Lord Rodney the French fleet bore alternately away and escaped, while the English, from the damage sustained in hulls and rigging, were unable to continue the pursuit."

Clerk further undertakes to show that whenever the French kept to windward, they were careful never to take the initiative and seek a battle, unless the odds were clearly in their favor.

This is illustrated by Rodney's two engagements on the 15th and 19th of May, 1780, near Martinique; Sir Saml. Hood's engagement of the 17th of April, 1781, near the same place, and by Admiral Keppel's in 1778 off Ushant, already referred to. In each of these fights the fleets crossed on opposite tacks, exchanging their fire in passing. In the last case the French fleet, having the wind, ran down and reformed to leeward. Subsequently, in Arbuthnot's fight off the Chesapeake, the French admiral put in practice the same tactics. "It is by such investigations only," he says, "that it can be explained how two adverse fleets, amounting to thirty ships of the line each, carrying above 36,000 men, after having been brought in opposition of battle, and sustaining a furious cannonade from 4000 guns, besides musketry, have been brought to be separated again without effect, without the smallest apparent decision—that is, without the loss of a ship on either side, and sometimes without the loss of a man, although the rencounter has often been said to have been within pistol-shot."

On board the Ramilies,* Admiral Byng's flagship, in the fight with the French off Toulon, no one was even wounded.

* Read the account of the loss of the Ramilies in 1782 with Admiral Graves on board. She was hove to under the mainsail on the larboard tack. The admiral was saved and all the crew.

Such, says an able English authority, in commenting upon Clerk's essay, was the state of Naval Tactics at the beginning of 1782. "During the whole war our fleets had invariably been baffled, disabled, worsted. Our admirals adhered, invariably, to the established mode of attack, and endeavored to obtain a windward position before they began to engage. The French, relying upon our want of penetration to discover, or of skill to counteract, this new system of defense, never failed to accomplish the object of their expedition, and to disable our ships, while they preserved their own. Dispirited by the failure of our arms in the American war, we beheld ourselves uniformly baffled on our own element, and we began to apprehend a decay of spirit in our officers and seamen." When we consider that this language was used by McArthur, the author of the well-known treatise on Naval Courts-Martial, and at one time Secretary to Admiral Lord Hood, it will add not a little to its significance.

Rear-Admiral Sir Charles Ekins remarks of Clerk: "In all his reasoning he shows with truth and success that our defeats were never owing to a want of spirit, but to *a deficiency of tactical knowledge*."

"No lessons in tactics," says one of the ablest naval essayists of the present day, "can be so valuable as those taught by the experience of the past. In no case has a victory been won over a fairly equal force where the ignorance of the one commander-in-chief, or the skill of the others, has caused the strength of the fleet to be dispersed and has spread the attack over the whole, instead of concentrating it against a part."

"All the painfully notorious battles of the last century—notorious by reason of the bitter feeling and angry, tragical courts-martial which followed their want of success—come distinctly under this category. From the time of Mathews to the time of Rodney we were trammeled and bound to a false system which, when skilfully opposed, could not, and did not, lead to any results other than disappointment and loss. The attack was made in line against line, if possible, ship against ship; and in no one instance was it attended with success. That the individual ships were, for the most part, skilfully handled and gallantly fought, may be conceded; that they were, singly, superior to the ships of the enemy, may be fairly maintained, but *collectively and as a fleet they were unable to accomplish anything*." *

*Prof. John Knox Laughton, R. N., Royal Naval College, Greenwich, to whom we are indebted for many valuable lessons.—S. B. L.

These are certainly very candid admissions; but they are fully justified by history.

Coming to us, as they do, from authors of high standing and of intimate knowledge of the subject, these statements are of the utmost value to the naval student; and we cannot feel too grateful to those gentlemen who have had the enlightened spirit, the sense of justice, and the love of truth, to give the plain facts, though it should not always redound to the credit of the profession they so worthily represent.

We now come to the true cause of the difficulty under which the English labored, and to the secret of the so-called "new system" devised by the French. McArthur goes on to say, "Our officers were eminently distinguished by their gallantry and seamanship, *but they had hitherto bestowed no adequate degree of attention upon Naval Tactics.*" And yet, for the fifty years preceding the treaty of Paris of 1783, the English naval officers had been constantly engaged in war.*

French officers, on the other hand, seem to have paid great attention to Naval Tactics. Tourville, so highly eulogized by Macaulay, originated the best work on Naval Tactics (that of Paul Hoste) ever published.

D'Orvilliers, who fought the drawn battle with Keppel, was the author of a work on Tactics; and the Viscount de Grenier proposed a formation for battle and a system of tactics which was certainly a work of merit. The Viscount Morogues and others of more or less note had written on the same subject. Ramatuelle is worthy of careful study to-day.

Ramatuelle† observes: "The French Navy has always preferred

*However fully we may share the incredulity of Lieutenant Hatchway, there is that about the utterances of Commodore Trunnion which plainly indicates the drift of popular opinion in his day (1751) in regard to the average sea-fight. In speaking of one of his exploits the Commodore says: "Finding the Frenchman—the Flower de Louse—took a great deal of drubbing, and that he had shot away all our rigging, and killed and wounded a great number of our men, I resolved to run him on board; but Monsieur, perceiving what we were about, filled his topsails and sheered off, leaving us like a log upon the water." (Dr. Smollett was a loblolly boy on board the Suffolk, Commodore, afterwards Admiral Sir Charles Knowles, and was present at the attack on La Guira in 1743. "Peregrine Pickle" first appeared in 1751.)

†Cours élémentaire de Tactique navale: Dédié à Bonaparte par Audibert Ramatuelle, ancien Officier de la Marine militaire, Paris, 1802.

the glory of securing, or retaining, a strategic advantage, or a conquest, to the more brilliant, perhaps, but really less substantial feat of making prizes; and in that they approach nearer to the true ends of war. For what would the loss of a few ships be to the English? The principal aim is to attack them in their possessions, the source of their vast commerce and their powerful marine."

The superiority of the French as tacticians is well illustrated by the battles fought by Sir George Pocock and Monsieur D'Aché in the East Indies; and, better yet, by the series of battles between the Bailli de Suffren and Sir Edward Hughes on the same station in 1782 and 1783.

Both commanders-in-chief, being remote from their respective Governments, and beyond the reach of instructions, were thrown upon their own resources, and obliged to rely solely upon their own judgment in the conduct of affairs.

De Suffren recovered the Dutch ports of Trincomalee, which the English admiral had captured a short time before, and after a series of actions raised the blockade of Cudalore and relieved the garrison. The conflicts were terminated by tidings of peace, leaving the French, on the whole, masters of the situation.

In all the higher attributes of a naval officer, save hard and persistent fighting, De Suffren proved himself to be superior to his adversary.

Still another and more familiar illustration is to be found in our own early history, when, at one of the most momentous periods of the Revolutionary War, an English admiral was fairly outgeneraled by his more skillful adversary. It was when De Grasse lured the English squadron away from the relief of Cornwallis. The late Centennial celebration at Yorktown has revived the memory of the historical incidents of that period.

At no time has the French Navy received full credit for its share in bringing a long and trying campaign to a successful termination.

While extensive preparations were being made by Washington in May, 1781, to capture New York, then occupied by the English, word was sent to De Grasse, in the West Indies, soliciting his co-operation. About the middle of May a message from De Grasse reached Newport, where a portion of the French forces and a French squadron then lay, saying that he had sailed, not for New York, but for the Chesapeake. This completely changed the whole plan of operations and made the army of Cornwallis the objective point. Con-

tinuing the demonstration against New York, with a view to misleading the English commander-in-chief, the combined armies took up their march for Virginia, distant about four hundred miles, and in about one month's time came within sight of the English at Yorktown. On the 14th of September, Washington held a consultation with De Grasse on board the Ville de Paris, when arrangements were made to prosecute the siege of Yorktown.

Clinton, meanwhile, learning that the French squadron under Count de Barras had sailed from Newport for the Chesapeake, dispatched Admiral Graves with his squadron to intercept him.

On reaching the Capes of Virginia, Graves was surprised to find the French squadron at anchor in the Bay. De Grasse, on his part, expecting to see the squadron of De Barras, was surprised to see the English ships. It was now that the skill of De Grasse displayed itself in the exercise of the highest order of strategy. He immediately proceeded to sea, and, practising the policy so often resorted to by the French, of allowing the English to gain the much-coveted weather gauge, he commenced a series of those indecisive actions which, as we have seen, so often characterized the naval battles of that day.

After each partial engagement the French would edge away to leeward, and, reforming the line of battle in a new position, await the attack. This manœuvring was kept up for five days; the English eager for a general and decisive battle, the French luring them away from the one objective point in the whole theatre of the war, the key of the entire plan of operations so laboriously prepared by Washington and his allies. At the end of about five days, judging the squadron under De Barras to be safe, De Grasse returned to the Chesapeake.

When Graves reached the Capes, he had the mortification of finding both French squadrons at anchor in the Bay, their united forces being much superior to his own. Completely outgeneraled, he returned to New York. The last avenue of escape left open to Cornwallis being thus closed by the French fleet, the destruction of the English army became inevitable.

To estimate the value of the service rendered by the French, and the full significance of the tactics of De Grasse, we have only to suppose that Admiral Graves, instead of following the French outside the Cape, had stood up the Bay for York River and effected a junction with Cornwallis. Notwithstanding the disparity of forces, the French having twenty-four ships of the line to nineteen of the English,

he could have rendered his position so strong that the French, exercising their extreme caution, would not have ventured to attack, even when joined by De Barras with ten ships of the line. Moreover, Admiral Digby, with a squadron, shortly after arrived at New York, so that when thus reinforced the fleet of Admiral Graves consisted of twenty-seven ships. Had the English commander-in-chief succored the besieged army, as a French admiral would have done, had their relative positions been changed, it would have given an entirely different complexion to the whole campaign of Washington, if it had not completely frustrated it.

The position of Admiral Graves may be likened to that of an army interposed between the parts of an enemy's extended lines in such a way as to be able to concentrate on either one of those lines before the other could be brought to its assistance.

Napoleon practised that species of tactics, which enabled him to beat his adversary in detail with brilliant success.

In this case before us, the objective point, Yorktown, was left open, so that the English admiral, without fighting, had only to sail in between the two French squadrons, establish himself in an impregnable position on the York River and render the relief so earnestly looked for by the English army. That De Grasse, with a numerically superior force, should have avoided a conflict with the English squadron, leads to the belief that the French must have been sensible of some inherent weakness, which is not fully explained by their known inability to refit their ships or replenish stores with the thoroughness and expedition of their adversaries. No doubt De Grasse was right in saying, on the occasion of his subsequent surrender to Rodney, that the English were, in naval matters, a hundred years ahead of them. We may except, as the English have so candidly done, the practical knowledge of Naval Tactics. Their superior skill in handling their fleets was forced upon them as necessary to their existence: it was the instinct of self-preservation.

The object of Clerk, to refer once more to the "Treatise on Naval Tactics," was to point out the grave defects of the English Fighting Instructions and to suggest the remedy. There seems to be no doubt that the English naval officers profited by the lesson, and, the ice once broken, there was no longer any hesitation in putting in practice the principal suggestion thrown out by the author, and one which is conformable to one of the oldest and best-known rules of the art of war—viz.: to inflict upon the enemy a decisive blow by concentrating

an overwhelming force upon a given point of his line, thus beating him in detail. It was to just such a manœuvre that Rodney owed his success on the 12th of April, 1782. How far Rodney was indebted to Clerk for the tactics which gave him the battle, it is unnecessary to discuss. Suffice here to say that in the memoirs of that officer the claim of Clerk is wholly denied; and that Sir Howard Douglas, in an able pamphlet, claims the honor in behalf of his father, who was Rodney's flag captain. Moreover, it has been pointed out by Clerk himself that the same manœuvre was performed by De Suffren, though not with equal success, in the battle with Sir Edward Hughes off Ceylon, in the East Indies, the very same day of Rodney's victory in the West Indies (April 12, 1782). The same tactics were referred to by Paul Hoste long before. They had been practised by Count d'Estrees when, in 1673, he cut through Prince Rupert's line.

It is quite certain, however, that the essay became an accepted authority, and led to a change in the Fighting Tactics of the English Navy. Thus it came that the naval battles of the French Revolution opened a fresher and brighter chapter in the history of English Naval Tactics.

Lord Howe, upon whom devolved the labor of reorganizing the English fleet and the Signal Book, after ten years of peace, led off in 1794 with the victory of the 1st of June. This was followed by the defeat of the Spanish squadron off Cape St. Vincent in 1797, where Nelson played so conspicuous a part; and in the same year Duncan, in two irregular columns, smashed through the centre and rear of the Dutch line at Camperdown, winning a brilliant victory.

The period culminated in Nelson and Trafalgar.

It is but fair to say here that it is claimed for Hawke, and with justice, that he founded the school of which Nelson became the most brilliant exponent.—("Life of Hawke.")

The English naval officers had, at last, begun to study Naval Tactics, leaving no longer to the French the monopoly of that secret of success. It is interesting to know that Nelson not only studied Clerk's Naval Tactics, but that it was his custom to give out to his captains problems in tactics for their solution. This had the tendency of leading their thoughts into those channels best calculated to prepare them for any emergency of battle that might arise, thereby laying down in advance the foundations for victory.

As the history of naval warfare may be divided into the three great periods of *Oars*, *Sails*, and *Steam*, so it is convenient for our present

purpose to divide the history of Naval Tactics under Sail into three periods. The first begins shortly after the peace of Westphalia, 1648, which terminated the Thirty Years War, and includes the three Dutch wars, when the English and Dutch contended for the sovereignty of the seas. It was during this time that James, Duke of York, originated the Naval Tactics of the English Navy and first established a regular order of battle (page 18, Vol. III., No. 1, Record of U. S. Naval Institute). It ended in 1673 with the defeat of De Ruyter by Prince Rupert. During this period the principal commands in the English fleet were held by officers who had enjoyed the advantages of a military training, and the battles were of the most decisive character.

The second period includes the times referred to by Clerk: the War of Succession, beginning in 1712; the war with Spain in 1718; the Spanish War in 1739; the war with France in 1744; the Seven Years War, from 1756 to 1763; and the American War, ending with the treaty of Paris in 1783. During this period the fleets of England were commanded by seamen pure and simple, who, ignoring the science of their profession, permitted themselves to be hampered by a set of arbitrary and insufficient rules. The battles fought during this period were, with few exceptions, indecisive.

The third and last period is characterized by a close attention to Naval Tactics and decisive battles.

It may be said to begin with Rodney's victory in 1782, and end with Nelson and Trafalgar in 1805.

The conclusion, which is not at all strained, is that the landsman with a military training was more capable of conducting the military movements of a fleet than the mere sailor who knew nothing of the science of war.

Charnock, in speaking of the Earl of Sandwich (Admiral Montague), says that "at the age of 30 (1655), bred to the Army, he was appointed joint commander of the fleet with Blake, a man undoubtedly possessed of the highest gallantry, but, like himself, totally unacquainted with every principle of Naval Tactics; yet under these very men, even at their first outset in their new profession, the British flag spread everywhere a terror and commanded a respect which, without intending to depreciate in the smallest degree the merits of their successors, we may truly say the greatest professional skill has never yet enhanced." It is evident that their ignorance of "every principle of Naval Tactics" was amply supplied by their knowledge of Military Tactics, which enabled them to direct

those more extended movements of a fleet comprehended in the term Grand Tactics, or the Tactics of Battle.

Prince Rupert and the Duke of Albemarle (Admiral George Monk) were styled "His Majesty's Generals at Sea." Monk may have excited the mirth of his sailors by calling out, "Wheel to the right," or "left," when he wished to tack ship; but he defeated the celebrated Dutch admirals, Van Tromp and De Ruyter, and was one of the best naval administrators England has ever had. Monk, it should be said, had enjoyed, during the earlier years of his life, a short experience at sea.

On the other hand, it was said of Sir Edward Hughes, a typical officer of the middle part of the eighteenth century, that he could handle his ship to admiration, but knew little about managing a fleet. Much the same may be said of Admiral Byng. A part of the evidence given on his trial conveys a valuable lesson. Captain Gardiner, of the Ramilies, 90, the flagship of Admiral Byng, testified that "he advised Mr. Byng repeatedly to bear down, but without effect; *for that on the day of the action the admiral took entire command of the ship upon himself*"; which means that he had no conception of the duties of his high office of commander-in-chief of a fleet. So of Mathews: he understood the practical part of his profession better than the theory, and "knew better how to fight, himself, than to command others to fight."

We cannot refrain from giving here a couple of pen-and-ink portraits of two distinguished officers whose services have been referred to. Of De Suffren the writer says: "He was cool and daring in action, crafty in policy, of ready wit, and of singular genius as a tactician, with much practical skill, added to a vast fund of theoretical skill: the most illustrious officer, without exception, that had ever held command in the French Navy." Opposed to him was Sir Edward Hughes: "Brave, skilled in his profession, of the old school, not fitted to receive new ideas, opinionated, perverse, with but little idea of tactics and less of policy, he was still, at all times, ready for battle. *He did not know much about manœuvring a fleet*, but he could handle his own ship to admiration; he had not much judgment as to the proper time to fight, but when he did fight, he did so with a courage that was proof against all odds."*

Sir Charles Ekins, in commenting upon the want of success of Admiral Graves, remarks that, "unfortunately, the fate of Mathews

* Professor J. K. Laughton, R. N.

and Byng was still fresh in the recollection of our naval commanders; and as in those cases disgrace or punishment alike awaited both the daring and the cautious, the conducting of a fleet in the presence of an enemy became a duty at once perilous and perplexing."

It is curious to note, as we may here, how the traditions of the English Navy seem to have completely usurped the place of original investigation. Keppel justified his conduct as having been formed on that of Russell, Hawke, and other great commanders, and the sentences inflicted upon Mathews and Byng affected generations of their successors.

The great lesson to be drawn from this cursory review of the history of Naval Tactics under Sail is, that the highest achievements of a navy are to be secured when, to the practical training from boyhood in all the details of the naval profession, there is added proper instruction in the science and art of war.

We must pause here for a moment to disclaim any intention of undervaluing the character of those many great seamen whose deeds embellish and adorn the pages of English naval history.

Drake, Hawkins and Frobisher (Lord Howard was not a seaman in the sense that Drake was), aided by the elements, scattered the Invincible Armada; but they lived before any regular system of tactics had been devised. And Anson, Hawke and Boscawen won their victories for the most part by superior numbers, wherein skill and tactics had little part. The battle of Quiberon, fought in bad weather, on a dangerous and unknown coast, must, however, stand out as a brilliant and exceptional victory.

If history be that "vast Mississippi of falsehood" Arnold has called it, the earnest student in his search for truth must carefully weigh the evidence, for and against, before concluding on the respective merits of the Fighting Tactics of the English and the French Navies of the last period of Tactics under Sail. Much praise is undoubtedly due to Nelson and his school; but what was the condition of the French Navy during the Revolution and the Consulate? Says an English naval essayist on this point: "The French, by their careful study of, and attention to, the details of naval architecture, of strategy and tactics, held their own against us for nearly one hundred years—not brilliantly, perhaps, but at any rate sufficiently—and it was not till the close of the century, when the study of tactics had been, in a measure, *forced upon us*, that we recovered our old superiority. As we improved, the French, victims of anarchy and internal confusion, deteriorated, and

thus, by the happy combination on our part of tactical study, practical skill, and constant experience; on the part of the enemy of ignorance and presumption, we won those great victories which mark the annals of the end of the last century and the beginning of this."*

These "great victories," then, were not due wholly to the prowess and skill of the English, but in a measure to the deterioration of the French; how great a measure that was, English writers themselves tell us.

But let us continue our study of English Naval Tactics.

In 1827 was fought, at Navarino, the last great fleet fight under sail; and the year after appeared the second edition of "Naval Battles," by Rear-Admiral Ekins, from which we make the following extract. He quotes another English admiral of distinction who uses this language: "If I commanded an English fleet opposed to a French one, I should not have the least objection to their cutting my line. I should probably myself break all order of battle, in order to prevent their cutting off any particular ships, and then, behold! the old story: I have them in action, ship to ship. This is the great secret of *our* tactics; that of the French to prevent it.

"I fairly own," he continues, "that I hope close action, ship to ship, will ever be the first object of a British naval commander-in-chief." And Admiral Ekins adds, with a burst of fine enthusiasm: "This is bravely said by the gallant son of a noble chief, and let the British Navy say, *Amen!*" This may be admirable as a specimen of rhetoric, but, certainly, very poor tactics. The passage is not without value, however, as corroborative of one of two theories: Either the English had been betrayed into over-confidence by the demoralized condition of the French Navy, and the consequent ease with which victories over it were gained, rendering skillful tactics unnecessary—and there is much to support this view—or, that after Trafalgar the English Navy relapsed into what has been well called the "Dark Age" of Naval Tactics. As late as 1828 two distinguished British admirals coolly tell us that the secret of their tactics is "close action, ship to ship"—a principle directly opposite to what their own Nelson and his school taught. His teaching, and the teachings of all great captains, both on shore and afloat, is to put *two* against *one*. To understand this fundamental principle is to understand the very root and groundwork of Grand Tactics; and to be able to carry out this principle in battle, is to exhibit the highest skill as a tactician. What,

* Prof. J. K. Laughton, R. N.

then, must we say of the Ekins school? Sir Samuel Hood, with twenty-two ships, when standing in to engage the French fleet of thirty-three sail of the line under De Grasse (anchored at Basseterre, St. Christopher, in 1772), designed to throw the whole weight of the attack on the head of the French column and crush that before the rear, which would have been thrown out, could possibly come to its succor. The French, notwithstanding their superiority, as a whole, no doubt escaped an overwhelming defeat by getting under way and standing out to sea. The same plan of battle was carried out at the Nile. The head of the French column was doubled upon and crushed, while the rear was completely thrown out of action. What Nelson meant by writing to Duncan, after Camperdown, that he (Nelson) had profited by his (Duncan's) example, is not precisely clear. In the battle of Camperdown, October 12, 1797, Duncan made signal to form line; but, not waiting for all the ships to come up, he and his vice-admiral, Onslow, led down on the enemy in two irregular columns, not unlike the manner in which Nelson and Collingwood led the attack on the allied fleets off Trafalgar. In both cases the entire English fleet did not cut through the enemy's line, but some "brought to" to windward, thus placing the enemy between two fires.

Nelson, in his general order (dated on board the Victory off Cadiz, Oct. 18, 1805), divided the fleet into two lines, sixteen ships in each line, with an advanced squadron of eight of the fastest-sailing two-decked ships, which eight ships, added, if wanted, to either of the two lines (as the commander-in-chief might direct), would swell that line to twenty-four ships. Those eight ships constituted the reserve. Having made his general disposition, he adds—and here lies the gist of the whole matter—"The impression of the *whole British fleet* must be made (with the intention of overpowering it) on that *portion* of the enemy's line rearward from the third or fourth ship ahead of its commander-in-chief presumed to be in the centre. I will suppose the twenty enemy's ships ahead untouched."* That is to say that, by

*On taking command of the fleet that was destined to operate against the combined forces of the enemy, Nelson summoned the admirals and captains of the fleet into the cabin of the Victory. "When I came to explain to them my plan of attack," he wrote to an intimate friend, "it was like an electric shock: some shed tears; all approved. It was new, it was singular, it was simple, and from admirals downwards it was repeated, 'It must succeed, if ever they will allow us to get at them.'"

Collingwood said the plan of attack was irresistible.

doubling on the enemy's centre and rear, he threw the entire van out of action.* And yet, nearly a quarter of a century after Nelson's splendid illustration of a well-known principle of the science of war, we find two distinguished admirals of the British Navy telling us that the secret of their tactics is to "place ship against ship."

Leaving the sail period, let us now consider the state of Naval Tactics at the present day.

In an exhaustive article on the subject, which appeared a few years ago, the very able writer declared that, in the British Navy, Naval Tactics "*had not been so much neglected as despised.*" Just think of that! "*Not so much neglected as despised.*" He says: "In that service no tactical maxim has ever been held in so much honor as the simple phrase which asked only for a fair field and no favor."

"Plenty of sea room and a willing enemy," he continues, "was a formula which adequately expressed the aspirations of a body of men strong in their confidence of their superior seamanship and of their undoubted valor and endurance." Evidently, for such men, if such indeed there be in the English Navy, the lessons of Hawke and Nelson have been given in vain.

As late as 1872 there were a number of English writers who agreed in thinking that, notwithstanding their magnificent fleet of ironclads, they were still "no more than groping after something definite which it was hoped might arise at a future time." They had not yet a perfectly settled drill to guide them in their fleet evolutions.

Another author, writing about the same time, says: "The naval student is brought face to face with the great difficulty of modern Naval Tactics—the choice of weapons. What would be the English choice, should war come upon us now? It is somewhat painful to note that we have no choice. We vaguely hope that a wise choice

*It may not be out of place to call attention just here to the expression "breaking the enemy's line," so often met with in naval history. In Captain Montagu Burrows' "Life of Lord Hawke" the author says that "Lord Rodney was not the first to whom credit is due for '*breaking the enemy's line*,' an operation he put in practice with distinguished results in his famous battle of Dominica, and which after 1782 became the tactics of the British Navy."

Now, simply breaking the enemy's line amounts to very little in a tactical point of view, and may, if the opponents are fairly matched, be attended with evil results. But the author goes on, in tracing the development of fighting tactics, to explain that "the next step was to cut through the enemy's line and *double the force* on each ship so cut off. After the time of Nelson any other method seemed inconceivable."

will in some way be disclosed to us, and we do not take a great deal of trouble to see how things point. The position we hold is dangerous and improper." He continues: "While each of the four modern naval weapons, the gun, the ram, the Harvey torpedo, and the Whitehead torpedo, has its advocates, the great mass of naval men simply look on."

In the English Naval Prize Essay of 1879 the author says: "Evolutions are not tactics. Evolutions are simply fleet drill: the Signal Book is a drill book." He then proceeds to criticise the Signal Book, winding up with the remark: "Are there no broad principles which might be shadowed forth in the Signal Book? At present, it must be admitted, we are groping in the dark. Our evolutions and manœuvres have no direct bearing on battle formations. .... Modern naval warfare has so changed," he says, "and is in such a state of transition, that, failing a direct order from higher authority to deal with tactics, modern Signal-Book committees *have agreed to ignore them*, except so far as an occasional verbal change in an old signal might be adapted to modern warfare." Here, then, lies the whole trouble: the English have made no serious effort to get up a modern Code of Fighting Instructions. The essayist is not without words of praise, however, for the Signal Book, deficient as it is. "If," says he, "we turn to the definitions, we see a great improvement has taken place in recent editions, the terms 'guide of a fleet,' 'guide of a column,' and others, being comparatively new. The term 'column' is also new, and is now used to mean '*any number of ships in a distinct body, whether in line ahead, line abreast, or otherwise.*' The word," he adds, "has been objected to, with justice, as having a forced meaning, but at least it *describes clearly* a body of ships in any formation, and this was previously much required."

Further on he says: "Alluding to the old Signal Book" (and the new one, he tells us, is a mere transcript with a few extra notes and observations), "we ask if we are right in supposing that *all these signals, evolutions and manœuvres are intended as a groundwork for tactics? And, if so, where are the tactics?*"

Another writer asks the same question: "But are even the evolutions prescribed for the squadrons sufficient? *If battle is their object, where are their formations or plans of attack which they recommend?*" The former essayist answers the question himself by saying: "We have been living in peaceable times, and battle *and action*

signals have been dropping out of the Signal Book. What remains? Just ten articles of instructions for action which are mostly obsolete."

It must be admitted that these remarks of English Prize Essayists hold out small encouragement to hope for much instruction in tactics from the English Navy. And there is reason to believe that other navies are pretty much in the same unsettled state as to the best system of Steam Tactics, both Minor and Grand. Commander Hoff, who has taken great pains to gather together under one cover all that is latest and best of the published opinions on the subject, quoting from English, French, German, Italian, and Russian and Belgian writers, comes to the deliberate conclusion that "all of them are more or less unsatisfactory."

The conclusion forced upon us is inevitable—that we must begin *de novo* and build up this science for ourselves.

We might very well conclude here, but for one or two remarks of the distinguished officers just quoted which require a passing notice.

One writer says: "Evolutions are not tactics, though they may form the basis on which tactics are founded." And again, speaking of the Signal Book as a manual of drill in fleet evolutions, he asks, "Where are the tactics?" And again, another officer asks, in speaking of fleet evolutions in the Signal Book, "If battle be their object, where are their plans of attack?"

To these several remarks we may repeat that "Tactics is the Art of Military Movements." This applies to the movements of a fleet, or its evolutions. Hence, the evolutions laid down in the Signal Book do constitute, in themselves, what is known as Minor Tactics. Further, that the writers quoted have confounded two distinct branches, viz.: Minor or Elementary Tactics, which is limited to evolutions (see Introduction), and Grand Tactics, or the Tactics of Battle. This distinction is made by military writers, and it would be well for us to adopt it, here and now, for our Naval Terminology. We will thus avoid any confusion of ideas. In the English Navy they had for generations of flag officers the Fighting Instructions, and in France the Ordonnance du Roi, to both of which reference has been made. These comprised the Grand Tactics of the Sail Period. The great want now felt in both those navies are modern Fighting Instructions. That is what they are striving for. But, as we have said, and say again, nobody, to our knowledge, has arisen, so far, who has shown himself competent to draw them up.

Now, Elementary Tactics, or the system of fleet evolutions laid down in the Signal Book; Grand Tactics, or the manner of forming a fleet for battle, and for conducting it in battle, and Strategy, together constitute the science of naval warfare; and that is what we are now to study.

In starting out with a new study, it is not desirable to retain the terminology of an obsolete system. The English and French have both fallen into this error. The English still cling to the terms *line ahead, line abreast,* and *line of bearing;* while the French retain the terms used by Paul Hoste: *La Ligne de File, La Ligne de Front,* and *La Ligne de Relevement.* Now, strictly speaking, the term *line of bearing,* having reference to the wind, is inapplicable to steam tactics. It was a line six points from the direction of the wind, and a fleet was on the starboard, or larboard, line of bearing according as the ships composing it could fetch, by a simultaneous movement, into the line of battle on the starboard or larboard tack. The term is a convenient and expressive one, however, and having been adopted by writers on steam tactics, it should have a modified and precise definition given it.

Unhampered by traditions as we are, let us at once adopt the shorter, simpler, and equally expressive terms of *Line, Column* and *Echelon,* and their derivatives, to express the various formations of a fleet. We shall then avoid such clumsy expressions as *line ahead in single column,* and many similar ones common to writers of the day.

Our terminology should be precise, our definitions clear. Where old terms will answer, it is certainly well to retain them, even if the sense must be modified. But when we are actually wanting in terms, we may be safe in taking such as have passed into the currency of military literature.

Our attention, then, will be first directed to Elementary Tactics; next, to the Tactics of Battle, and lastly, to Strategy.

U. S. NAVAL INSTITUTE, NORFOLK BRANCH.

FEBRUARY 2, 1887.

CAPTAIN GEORGE BROWN, U. S. N., *Vice-President*, in the Chair.

THE NAVAL STATION AT NORFOLK, VA.

BY LIEUTENANT R. M. G. BROWN, U. S. N.

The vicinity of Norfolk possesses many great advantages for a dockyard, and it is a remarkable fact that not a single objection can be urged against making it the great shipbuilding yard now so urgently needed.

Just before the breaking out of the War of the Revolution the British Government established a naval station on the present site. This point was selected in preference to all others after a careful survey of all the ports in the North American dominions of Great Britain.

Sir George Collier captured Norfolk and the Navy Yard in 1779, but was ordered to abandon it, which he did under protest. In his letter protesting against the evacuation he said: "Permit me, as a sea officer, to observe that this port is an exceedingly safe and secure asylum for ships against an enemy, and is not to be forced even by great superiority."

During January, 1800, at the request of the President of the United States, the General Assembly of Virginia passed an act authorizing the sale of the property known at that time as Gosport to the United States, to be used as a permanent navy yard. It was accordingly sold to the United States for $12,000, there being sixteen acres in the property. The Yard was greatly increased in size about 1826 and 1827. It now contains eighty-two and one-half acres, and has a water front of 3860 feet, or about three-quarters of a mile. In 1834 the dry-dock, costing nearly a million of dollars, was completed. Saint Helena was added to the station in 1847, and the War Department turned over Fort Norfolk to the Navy in 1849. About 1878 and 1879 the main

powder magazine was moved down to Craney Island, and Fort Norfolk has since been used only as a temporary storehouse for powder.

In accordance with an act of the General Assembly, Governor Tazewell, in 1835, conveyed to the United States the jurisdiction over the new purchases, and also over the Fort Nelson property now used for the Naval Hospital. In these acts ceding property to the United States, the Commonwealth of Virginia reserved the right of executing any process whatever within the limits ceded, and also a provision was inserted that the property would revert to the Commonwealth of Virginia in case the Government of the United States ceased to use it for the purpose specified.

Captain Lull, U. S. N., in a short history of this Navy Yard, says: "No navy yard belonging to the United States, from its geographical position, is more important than that at Gosport, Va. Located near enough to the entrance of the Chesapeake Bay to be easily accessible, it is, at the same time, in a position readily defended from attacks either by land or by water, and one, as has been repeatedly shown, which can be held by a small force against a very largely superior one. There is in the vicinity an abundant supply of timber and other material, while the close proximity of a populous city secures to it the command of all the skilled labor that can be required.

"Such is the mildness of the climate that work of all sorts can be carried on at all seasons of the year without interruption. Hampton Roads, the outer harbor, is an excellent point of rendezvous for a fleet or squadron.

"A glance at the map will demonstrate the very great importance of a naval station in this vicinity. The Chesapeake, with its navigable tributaries, penetrates into the heart of several of the richest States in the Union, reaching to the national capital. A foothold in its waters would, therefore, be of the utmost strategic importance to an invading enemy, and would probably be one of the earliest objects sought by them, as past history has fully shown.

"The width of the entrance of the bay is so great that it would be impossible to defend it except by a naval force, which should have a repairing, coaling and victualing station as near at hand as possible, consistent with entire defensibility for itself, with a reasonably secure outer harbor, large enough for the necessary manœuvres of a squadron in getting under way and forming. All of these conditions are admirably filled by the location of the Gosport Yard."

The many changes in naval warfare in recent years have put the cities near deep water at a great disadvantage for defense against an enemy. The great range of modern ordnance enables a fleet to lie off a city like New York and destroy it without entering its harbor at all. Submarine mines, torpedoes, and rams can only be used with advantage when an enemy has to approach a city through narrow channels and rivers. They would all prove most effective in the defense of the Navy Yard at Norfolk. It is a great disadvantage to have a naval arsenal near a large and opulent city, the latter naturally inviting the attacks of an enemy, who thus has a double inducement to attempt the capture. The only advantage derived from having a navy yard near a large city is on account of the ability to obtain skilled labor; but the lack of skilled labor has never been felt at Norfolk, nor will it be as long as the rents are so low and the markets so cheap. Besides, the laboring man has to incur but little expense for warm clothing in this climate. No more reliable laboring men can be found than in this vicinity.

So much has been said of the climate of Norfolk that it is unnecessary to speak of the great advantage possessed by this Navy Yard over all others on the coast in that respect. The great advantages in regard to coal, iron and lumber are also well known. The convenience of fresh water, where iron vessels can be preserved when not in commission, is also a great advantage that Norfolk possesses.

The Navy Yard can be extended very cheaply, if desirable. The plant can, at an expense of less than $100,000, be enlarged and improved so as to be equipped for building the iron ships required for the new Navy.

The stone dry-dock is an excellent one, but too small for the new ships. It is believed that Congress will at this session authorize the construction of a Simpson dry-dock,* located where the wet-dock is now, and large enough for any vessel of the Navy. This is much needed, and no labor or pains should be spared to obtain the necessary appropriation. As the South has but one navy yard in use, it would seem that Southern Senators and members of Congress should be appealed to and asked to support it. It is greatly to be regretted that an appeal is necessary under such circumstances.

An inexhaustible supply of the best fresh water can be obtained from Lake Drummond. It has long been known in the Navy by

* The construction of the dock in question has been authorized by act of Congress since the reading of this paper.—ED. COM.

the name of "juniper water," and has always had a high reputation for purity and healthfulness. There is great necessity for proper water-works connecting Lake Drummond with the Navy Yard, and it is clearly the duty of the Government to assist this undertaking, as it would insure the Navy Yard from fire much more efficiently than the expensive fire department now maintained. Besides, it would allow of proper sewerage and sanitary arrangements within the Navy Yard. Ships could also be furnished with fresh water at the dock, instead of by means of the expensive and unreliable method of water boats now in vogue. I understand that the Civil Engineer estimates the cost of laying the necessary mains and pipes throughout the entire Navy Yard at $17,000. Of course, an annual sum must be paid to the water company for supplying the water, but this has always been done at the other yards.

There is also a necessity for quarters for all officers attached to the Navy Yard. A like necessity exists for quarters for the officers and men of the Marine Corps. This should be constantly urged. It enables an officer to be near his post of duty both by day and night, and would do much to make the station a popular one, as it was previous to 1860.

A proper electric-light plant should be installed in the Yard, so that work could be carried on at night, if necessary, as well as by day.

It is true that much has recently been done to improve the condition of affairs. A much-needed fire-alarm system has been successfully inaugurated; a new and larger picket launch has been put in commission for the use of the officers and employes; a large tug has been fitted out and commissioned for Yard duty; an office has been built for the officer of the day; and many minor improvements have been made.

What seems to be one of the evils at present is want of concentration. It is too inconvenient to reach different points. The Franklin should, in my opinion, be moored alongside the Navy Yard wharf. A Herreshoff launch should be furnished the ordnance officer, so that he could easily inspect his different storehouses and magazines.

It would be an excellent thing if a street railway were built from the Navy Yard gate to the Norfolk ferry, and the ferry boats should run more frequently. This would enable Norfolk laborers more easily to reach the Navy Yard.

There seems to be no valid reason why the Hospital grounds should

not be converted into a public park; and the same can be said of the farm called Saint Helena, opposite the Yard, in the town of Berkley. Of course, care should be taken that the interests of the Government are properly protected.

In conclusion, I would say that while it is the interest and duty of a naval officer to point out the advantages of location, etc., of this Navy Yard, it is to the interest of Virginia and of the whole South that a demand for iron and steel be encouraged in a home port, in order that the expense of transportation may be reduced, and that the furnaces of the South may compete successfully with those of the North in furnishing steel for the new Navy.

DISCUSSION.

Captain GEO. C. REMEY, U. S. N.—*Mr. Chairman and Gentlemen*:—Having regard solely to geographical location and site, I regard the Norfolk Navy Yard as the first in importance of all the navy yards belonging to the Government. Believing this to be so, I think it is the duty of the Virginia Representatives in Congress to urge and insist that ample appropriations be made to make the present Yard a first-class dockyard. To do this will require a comparatively large expenditure of money, but the day may come, and be not far distant, when such expenditure would be regarded as a wise one.

It seems to me, if the Virginia Representatives in Congress would endeavor to enlist all the Representatives in Congress from the South to advocate a modern dockyard, to be made of the present Yard, that appropriations looking to this might be secured if for no other argument than that this Yard is practically the only one in the South. Having this in view, it would be the duty of the Navy Department, and I do not doubt a pleasure, to elaborate plans so that all improvements made would be done systematically, looking to a modern dockyard as the result.

Regarding the facilities for obtaining iron and steel, it is evident from common report they will be produced and manufactured in large quantities in the States of Alabama, Georgia, and Virginia.

Statements have been lately made in the public press that iron and steel can be produced in Alabama cheaper than elsewhere in this country. Whether this now be so or not, it is evident to the careful observer that iron and steel are rapidly becoming most important interests in these States.

Surgeon GEORGE A. BRIGHT.—*Mr. Chairman and Gentlemen*:—As to the sanitary condition of the Norfolk Navy Yard, so far as it depends on local climatic causes, I may say that while there are a good many cases of malarial fever during the warm season, most of these cases have been light, and none of them really grave, during my experience of the latter half of 1886. I have seen no reason, then, to believe this station particularly unhealthy.

As to the water supply for the use of the houses and shops, for flushing sewers, and for use in case of fire, etc., the supply is unsatisfactory, depending upon the rainfall, and collected from the roofs of the various buildings in the Yard: it is stored in a reservoir under ground, whence it must be pumped for daily use. It is greatly to be desired that the Yard be connected with the proposed system of waterworks of Portsmouth.

The marine barracks of the Yard are disadvantageously placed in all respects. They are at the extreme south end of the station, remote from everything. The building is very plainly constructed, of wood, only one story high, and the floor is raised only a few feet above the soil. It is situated on damp ground, is insufficient in size, and insufficiently lighted. The closets are at a distance from the main building: they should be connected with the barrack by a covered way, as a protection in bad weather.

Assistant Naval Constructor BOWLES.—*Mr. Chairman and Gentlemen*:—An attempt to describe or set forth, even briefly, the necessities of this Yard in order to make it a busy, efficient and economical shipbuilding yard, requires careful consideration. The possibilities of this Yard are unsurpassed. Actually, at present, we have not the necessary furnaces, tools and appurtenances for building the smallest iron or steel ship. For a small sum—say not more than $50,000—tentative arrangements could be made in a short time which would enable us to build steel ships, but neither expeditiously nor economically. To accomplish these desirable objects, and to make this Yard what its climate, accessibility, location, readiness of supplies, and admirable natural advantages would justify, will require an entire redistribution of the shops and a large outlay in tools and plant.

I have previously suggested to the author of this paper the advantage of a careful study of the reorganization of the Yard by a board of officers, who shall digest and prepare a plan and estimates of cost to equip this Yard for building and repairing ships of all types.

In reference to the dry-dock, I have one point to submit for discussion—namely, it is now proposed to convert the timber dock into a dry-dock. It seems to me that it would be a better plan to remove the timber, renew and deepen the quay walls, and make it into a fitting-basin, with shears, cranes, etc., for fitting engines and boilers, armor, guns, etc. The timber dock is at present surrounded by buildings available for shops.

Again, it is an advantage and economy in many ways to have the dry-docks near together. One set of pumping engines would answer for both, the character of the work at the docks is similar, the implements and accessories in docking and undocking are common. In my opinion, it would be very inconvenient to build another dry-dock so far from the present one as the timber dock. In active shipbuilding the necessity of a fitting-basin free from the effect of tidal currents and the movements of vessels in the stream would be greatly felt.

Among the disadvantages of the present arrangements in the Navy Yard are the location of the offices and the wide distribution of the shops, the lack of any means of communication. A telephone system would be found indispensable in busy times.

I would ask, also, Mr. Chairman, if it be not true that, of all our navy yards, Norfolk has the most convenient and abundant facilities for the supply of an excellent quality of semi-bituminous coal, for which all our new vessels are designed.

THE CHAIRMAN.—*Gentlemen* :—The Department recognizes the importance of introducing water in the Yard, and the Chief of Bureau of Yards and Docks has asked for an appropriation for the purpose of laying water mains, putting in hydrants, etc., and connecting the system with the 8-inch main of the Portsmouth Water Company which runs to the main entrance gate. We would then not only have an ample supply of water for fire and other purposes, but there would be much less loss of time than now exists by the employes going to the water front.

Long before Norfolk or Portsmouth had any railroad connections with the interior this station was regarded as second to none as a rendezvous for our ships for obtaining needed supplies. How much more important it now is can be readily seen, more especially as a coaling station. The modern ships are designed to burn bituminous coal, and we now have two railroads connecting with coal fields, and coal can be brought by rail to St. Helena direct from the celebrated mines where we get the "Pocahontas steam coal," than which none superior for steaming purposes is found in the United States.

Should this become an active shipbuilding Yard, many changes would have to be made in the location of offices, as the heads of departments should have their offices near the shops of which they have charge. Then, with a local telephone system in the Yard, the commandant could communicate with the officers without loss of time.

The necessity for a marine barracks at this station has long been recognized by every one except the Appropriation Committees of Congress. The efficiency of the guard is not promoted by the discomfort to which the men are now subjected.

As is now well known, the South is advancing rapidly in the development of its iron and steel industries, but the Southern steel manufactures cannot at present compete with those of Pennsylvania on account of the distance the steel has to be transported in order to reach a shipbuilding establishment. A shipbuilding establishment at Norfolk actively engaged in building iron and steel ships would remedy this evil and put the two sections on a more equal footing.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

ECONOMY OF COMPOUND DIRECT-ACTING PUMPING ENGINES.

By Passed-Assistant Engineer C. R. ROELKER, U. S. N.

The following account gives a description and record of tests made by the writer in the early part of 1886 on the new compound pumping engine then recently erected by the Blake Steam-Pump Company at the Kings County Oil Works, Greenpoint, L. I. These tests were made with the view of ascertaining the economy to be gained by the use of compound instead of simple engines for direct-acting pumps.

DESCRIPTION OF THE PUMPING ENGINES.

The pump draws the water from Newtown Creek, through a suction pipe 16 inches in diameter and 222 feet 4 inches long, and delivers it into a large main 14 inches in diameter, whence it is distributed, through branch pipes varying in diameter from 8 to 12 inches, to the cooling coils of the oil refinery and for other purposes. The aggregate length of the main and branch discharge pipes is 1572 feet. The height to which the water has to be raised on the suction side varies with the tides; the water is delivered ordinarily against a head of about 35 feet.

The pumping engine consists of a horizontal double-acting pump, actuated directly by a compound steam engine having one (1) H.-P. and one (1) L.-P. cylinder. The H.-P. cylinder is secured directly to the inner head of the L.-P. cylinder and, by means of four (4) stay rods, to the pump cylinder; the axes of the three cylinders lying in the same straight line. The piston rods of the pump and of the two steam cylinders are secured to a common cross-head. The pump is of the well-known Blake pattern, and has air vessels of ample capacity fitted to the suction as well as to the discharge side.

The valve gear of the steam cylinders contains the latest improvements made by the Blake Steam-Pump Company. The slide valves of the H.-P. and L.-P. cylinders are coupled together and worked jointly by an auxiliary steam cylinder located above the valve chest of the H.-P. cylinder. The piston rod of the auxiliary steam cylinder and the main valve rod are coupled to a lever the arms of which are so proportioned as to give the proper travel of the slide valves for the full stroke of the piston. An auxiliary slide valve, operated by means of a tappet and lever from the main cross-head, regulates the movements of the auxiliary piston. The exhaust of the auxiliary cylinder is led to the condenser. The L.-P. cylinder is provided with an adjustable cushion valve at each end, by means of which the length of stroke of the engine can be regulated to a great nicety.

The H.-P. cylinder exhausts into a receiver, which is a separate vessel located under the H.-P. cylinder and having a capacity equal to about 2.17 times that of the H.-P. cylinder. The receiver is considered essential to the smooth and regular working of the direct-acting pumping engine, as it prevents the shock resulting from the immediate impact of the high-pressure steam discharged from the H.-P. cylinder into the L.-P. cylinder. It also serves as a "separator," furnishing dryer steam to the L.-P. cylinder. Both cylinders are thoroughly steam-jacketed at the ends as well as at the sides: the steam for the jackets being taken from the main steam pipe. The drain pipes of the jackets and of the receiver are connected with automatic steam traps. The cylinders and receiver are covered with a thick layer of hair-felt and completely lagged.

The exhaust of the L.-P. cylinder passes ordinarily into a cone jet condenser, the condensing water being taken from the discharge of the pumping engine, and a small Blake steam pump serving as an air pump. During these tests, however, a "Wheeler surface condenser" was used instead of the cone jet condenser. The steam cylinder of the air pump exhausted into the atmosphere during the trials.

Principal Dimensions of the Pumping Engine.

Diameter of pump cylinder, 24 inches; diameter of H.-P. cylinder, 12 inches; diameter of L.-P. cylinder, 24 inches; nominal length of stroke of pistons, 24 inches; extreme length of stroke of pistons, including clearances, 25 inches; diameter of pump piston rod, one (1), $2\frac{1}{2}$ inches; diameter of H.-P. piston rod, one (1), $1\frac{3}{4}$ inches;

diameter of L.-P. piston rods, two (2), 1¾ inches; valve ports of H.-P. cylinder, single, 1½ x 6 inches; valve ports of L.-P. cylinder, double, 1½ x 12 inches; travel of valves, 2¼ inches; diameter of auxiliary steam cylinder, 4 inches; stroke of piston of auxiliary steam cylinder, 8 inches; extreme width of pumping engine, 3 feet 1 inch; extreme length of pumping engine over bolts of cylinder flanges, 13 feet 7⅛ inches; extreme height of pumping engine, exclusive of air chamber, 5 feet 8⅛ inches.

All the working parts of the pumping engine are made of the best material, finished and fitted in a substantial and workmanship-like manner. It works with great smoothness and regularity. The extreme differences of stroke observed during all the experiments did not exceed ⅛ inch. The nominal length of stroke was always exceeded, and the regulating valves acted with such nicety that the pistons were never observed to strike the cylinder heads, although they traveled the extreme length of the stroke. The pump is working continuously night and day, and is reported as giving complete satisfaction to the owners.

Manner of Making the Tests.

The tests took place on January 21 and February 13, 1886. The conditions of each trial were maintained as uniform as possible. The steam stop-valve of the engine was set for a certain speed of the pump at the beginning of each test, and remained unchanged during its course. The pressure in the water main and the speed of the engine were maintained as nearly uniform as the proper working of the plant permitted. No sudden fluctuations or changes of speed or pressure ever took place.

The test of January 21st continued for four hours. The engine was worked compound, all the steam jackets being in use. The piston speed of the engine during this trial was greater than that at which it works under ordinary conditions.

On February 13th the engine was run for one hour as a compound engine, with the steam jackets in use, but the piston speed and power developed were less than during the previous trial, being such as obtain in the ordinary working of this engine.

After the completion of this trial the engine was worked for two hours non-compound by admitting steam to both sides of the H.-P. piston continuously through the indicator pipes and cocks. Indicator cards taken from the H.-P. cylinder under these conditions showed that the fluctuations of pressure during the stroke were very small.

The piston speed and power developed were nearly the same as during the immediately preceding trial, but the steam was shut off from all the jackets.

Complete sets of indicator cards were taken at frequent regular intervals simultaneously from the water cylinder and both steam cylinders by three observers. The same indicators were used during all the trials, and the correctness of their scales was ascertained by comparison with a standard.

Readings of the steam, vacuum and water-pressure gauges, thermometers and counter, were likewise taken at frequent regular intervals and recorded in the log.

The exact length of the stroke was recorded, by a pencil attached to the cross-head, on a strip of paper.

The weight of steam consumed by the engine was ascertained by weighing all the water discharged by the air pump on carefully adjusted platform scales.

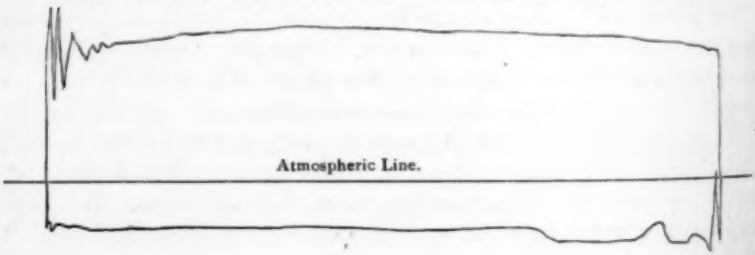
The weight of steam condensed in the jackets and receiver and discharged through the traps could not be observed in the course of the tests. The superintendent of the oil works, Mr. J. W. Van Dyke, had these quantities measured subsequently on two different occasions, for periods of four hours and two hours, while the pumping engine was working under normal conditions, and has kindly furnished the results to the writer.

The indicator cards hereto appended represent average conditions of the two trials of February 13, 1886:

FEBRUARY 13, 1886. CARD NO. 2. 11.55 A. M.

Single strokes per minute, 36.4; steam gauge, 60 pounds; vacuum gauge, 23⅞ inches; M. E. P., both ends = 26.05 pounds.

Diagram from Water Cylinder, one end. Scale, 20 pounds = 1 inch.



FEBRUARY 13, 1886. CARD NO. 2. 11.55 A. M.

Single strokes per minute, 36.4; steam gauge, 60 pounds; vacuum gauge, 23¾ inches; M. E. P., both ends = 43.18 pounds.

Diagram from H. P. Cylinder, one end. Scale, 31 pounds = 1 inch.

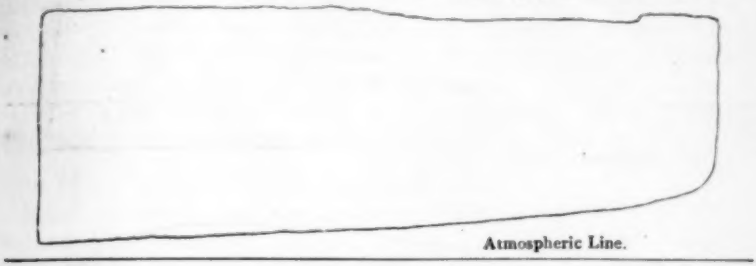
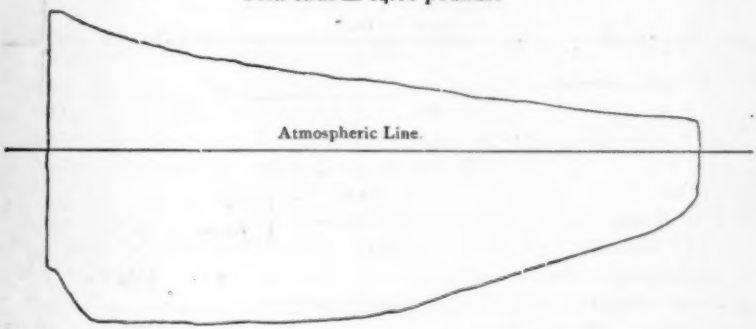


Diagram from L. P. Cylinder, one end. Scale, 9.8 pounds = 1 inch; M. E. P., both ends = 14.16 pounds.



FEBRUARY 13, 1886. CARD NO. 8. 3 P. M.

Single strokes per minute, 31.29; steam gauge, 57 pounds; vacuum gauge, 21.5 inches; M. E. P., both ends = 26.58 pounds.

Diagram from Steam Cylinder, both ends. Scale, 31 pounds = 1 inch.

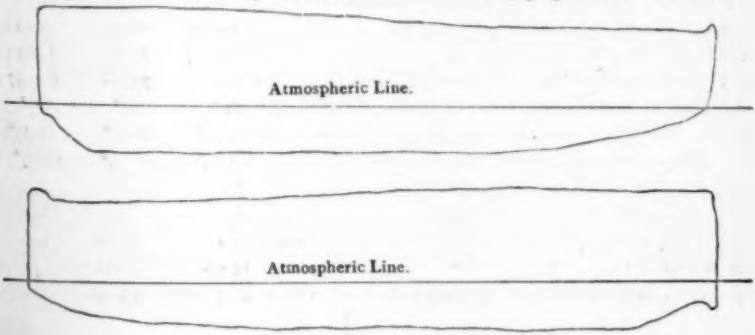
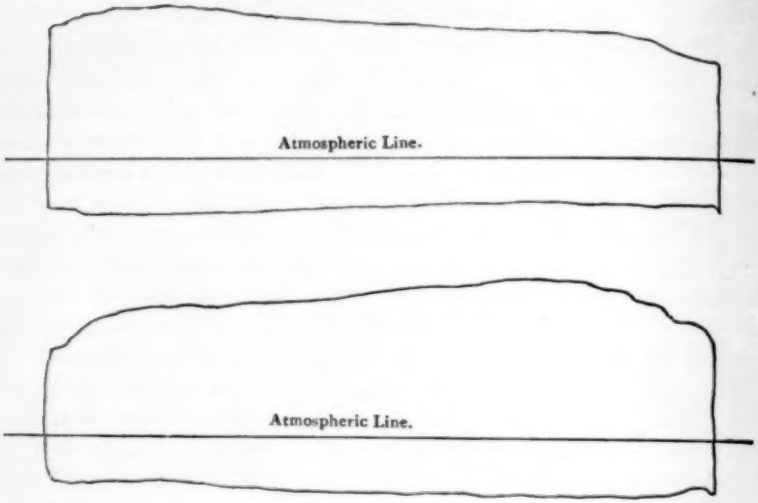


Diagram from Water Cylinder, both ends. Scale, 20 pounds = 1 inch; M. E. P., both ends = 24.483 pounds.



Results of Tests.

1. Date of test	Jan. 21, 1886.	Feb. 13, 1886. I.	Feb. 13, 1886. II.
2. Duration of test in hours and minutes	4 h.	58½ m.	2 h.
3. Steam pressure by gauge, pounds per square inch above atmosphere	58	61	56.375
4. Vacuum in condenser by gauge, ins. of mercury	24.5	23.8	21.67
5. Vacuum in suction pipe of pump by gauge, ins. of mercury	12.04	10.25	10.25
6. Pressure in discharge chamber of pump by gauge in pounds per square inch above atmosphere	14.61	16.88	14.53
7. Single strokes of pump per minute	54.9166	34.94	31.866
8. Length of stroke, inches	24.6987	24.75	24.875
9. Piston speed in feet per minute	112.997	72.06	66.047
10. Temperature of injection in degrees Fahr	32°	32°	32°
11. " " discharge " "	54.96°	80.2°	81.35°
12. Temperature of hot-well in degrees Fahr	116.85°	132.5°	140.5°
13. " atmosphere " "	71	...	...
14. Barometer, inches of mercury	29.98	...	...
15. Initial steam pressure in H.-P. cyl. above atm.	55.154	51.54	...
16. Final " " " " "	54.96	52.41	...
17. Mean indicated steam pressure in H.-P. cyl.	42.7347	43.19	...

18. Initial steam pressure in L.-P. cyl. above atm.	11.746	8.82	19.38
19. Final " " " " ...	5.8	2.6	18.5
20. Mean indicated steam pressure in L.-P. cyl....	16.589	14.21	26.97
21. I. H. P. developed in H.-P. cylinder.....	16.4355	10.58	—.25
22. " " in L.-P. "	25.6027	13.89	24.29
23. " " in both steam cylinders....	42.0382	24.479	24.04
24. " " in pump cylinder.....	41.3695	...	22.46
25. Total weight of water delivered by air pump during the test, pounds.....	4832	671.5	2885
26. Weight of water delivered by air pump for one hour, pounds.....	1208	688.7	1442.5
27. Weight of condensed steam discharged from jackets and receiver per hour according to test made January 27, 1886.....	139	88	...
28. Sum of two preceding quantities, being total weight of steam consumed in pumping engine per hour.....	1347	776.7	1442.5
29. Weight of steam consumed per I. H. P. of pumping engine, pounds per hour.....	32.4	31.3	60
30. Weight of steam in H.-P. cylinder at end of stroke in pounds per hour as shown by indicator.	913	564	...
31. Preceding quantity expressed in percentum of total weight of water delivered by air pump.....	75.58	83.35	...
32. Weight of steam in L. P. cylinder at end of stroke in pounds per hour, as shown by indicator.	1133	612	1032.9
33. Preceding quantity expressed in percentum of total weight of water delivered by air pump.....	93.79	88.86	71.65

Explanation and Discussion of Results.

Lines 3 to 14 of the preceding table contain the means of all the quantities recorded in the log for each trial. The steam gauge was attached to the steam pipe, close to the engine. The spring gauge connected with the pump-discharge (line 6) was located four feet higher than the indicator attached to the pump.

Lines 15 to 24 contain the means of the quantities computed from all the indicator cards taken during each trial. The indicated horse-power on lines 21, 22, and 23 is computed from the mean piston speeds (line 9), and the mean indicated pressures of all the cards taken during each trial (lines 17 and 20).

The quantity on line 21 for Trial II. of February 13—viz. —.25, represents the work done in overcoming the resistance of the steam in the H.-P. cylinder in passing from one side of the piston to the other side through the indicator pipe; this pipe, half inch in diameter, was

too small to make this resistance inappreciable. A number of cards were taken to determine this resistance.

The indicated horse-power (line 24) of the pump was computed from the mean indicated pressures of all the cards and the mean piston speed given on line 9. The cards taken from the pump cylinder during Trial I. of February 13 were rejected on account of discrepancies.

It should be remembered that the indicated horse-power of the steam cylinders (line 23) does not include the power required to work the valve gear, this being done by the auxiliary steam cylinder. The absence of all journal and cross-head-guide friction contributes to make the net effective power of these direct-acting pumping engines a large percentum of the indicated power of the steam cylinders.

The quantities on line 29 are computed for the indicated horse-power recorded on line 23, which does not include the power required to work the slide valves and gear, while the quantities on lines 25, 26 and 28 include the weight of steam expended in the auxiliary cylinder. This insignificant error does not affect the comparison of economic efficiency of the compound and non-compound engine.

Line 29 shows that the weight of steam consumed per indicated horse-power of the pumping engine, when worked compound with steam jackets in use, was 53 per cent. of the weight of steam consumed when it was worked non-compound and without steam-jacketing. A comparison of the quantities on line 33 proves that the steam-jacketing was very effective in reducing the cylinder condensation, and it contributed undoubtedly no small share to the economic efficiency of the pumping engine. It should, however, be stated that the L.-P. cylinder was larger than the steam cylinder of a non-compound pumping engine properly proportioned to the work to be done would have been. On this account the economic gain due to working the engine compound, as shown by the experimental results, is somewhat too great.

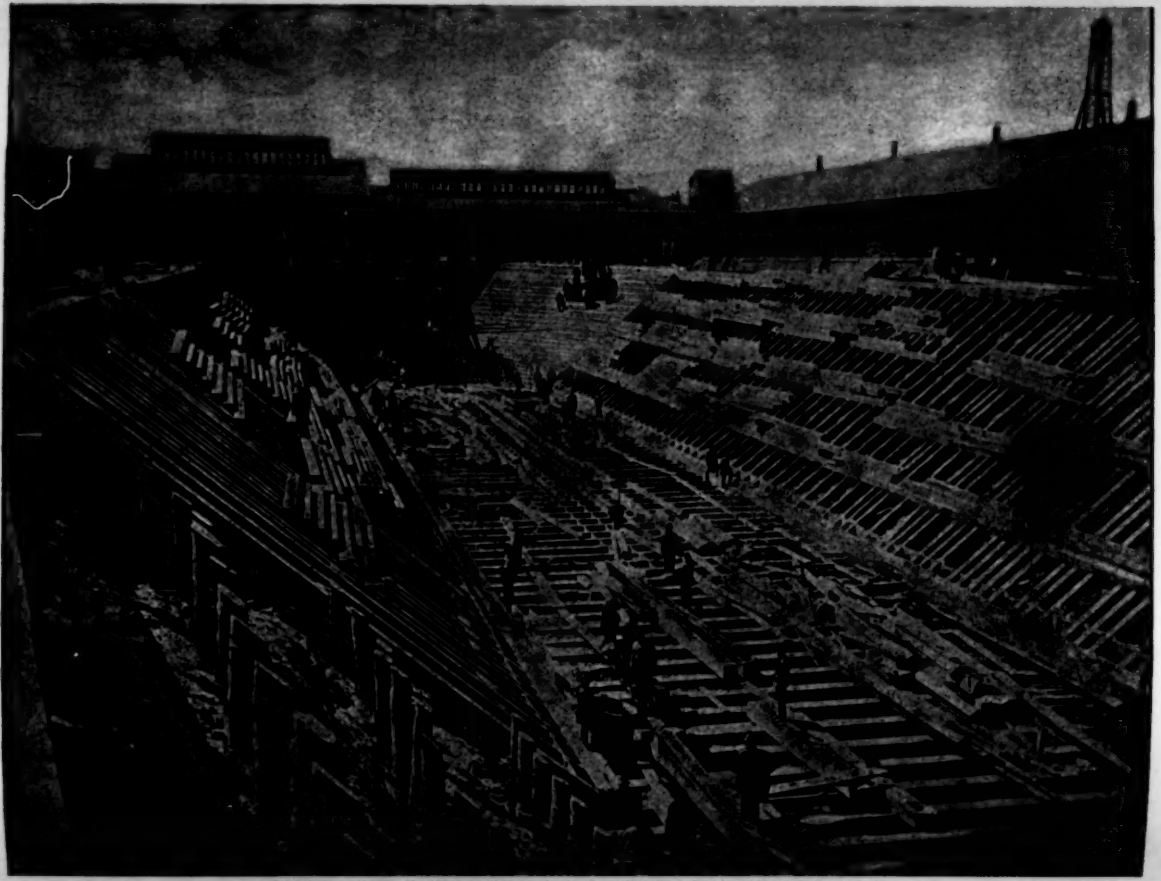
According to calorimetric tests made on January 27, 1886, the percentum of moisture contained in the steam supplied to the engine was 2.917 percentum.

The results of these tests are applicable to the pumping engines of the U. S. Ships Dolphin and Chicago, which were built by the Blake Steam-Pump Company, and resemble in type and proportions closely the experimental engine. These pumping engines have one (1) horizontal steam cylinder, 22 inches diameter by 24 inches stroke,

and one (1) horizontal double-acting circulating pump, 26 inches diameter by 24 inches stroke. The axes of the steam cylinder and pump lie in the same straight line, and the piston rods of cylinder and pump are secured to a common cross-head, from which the two vertical, single-acting air pumps are worked by means of a link and a double bell-crank lever. The steam cylinder is not steam-jacketed, but covered with hair-felt and wood lagging. A full description and illustrations of these pumps will be found in the *Mechanical Engineer* of September 19, 1885, where a thorough analysis of the excellent performance of these pumps during the several trials of the U. S. S. Dolphin is given.

The substitution of compound cylinders for a simple steam cylinder in the pumping engines of the Dolphin and Chicago would increase their weight about 1200 pounds—an insignificant amount, considering that this same weight represents the saving in fuel, for 36 hours' steaming, to be gained by compounding the engine.

A more serious consideration is the additional space occupied by the compound pumping engine—viz. 2 feet 3 inches in the direction of its length. But the saving in fuel must be considered as overbalancing greatly also this objection.



SIMPSON'S IMPROVED DRY DOCK, BALTIMORE, MD.,
WHILE IN COURSE OF CONSTRUCTION.

SIMPSON'S TIMBER DRY-DOCKS.

By Lieut.-Comdr. C. H. Stockton, U. S. N.

Congress during its last session having appropriated a sum of $1,100,000 for the construction of two timber dry-docks at such navy yards as the Secretary of the Navy may designate, it has been suggested that a few remarks upon timber dry-docks, of a descriptive and general nature, may be of interest to the members of the Institute and to the readers of its Proceedings.

The only excavated timber dry- or graving-docks that have been built upon our seacoast have been those known as Simpson's improved dry-docks. These have been duly inspected and examined by at least three boards of officers, composed either mainly or entirely of civil engineers and naval constructors, and approved and strongly recommended by them. By this system of docks (excavated docks) the best type of docking appliance can be constructed with rapidity, comparative cheapness, and of sufficient strength and durability.

The first dock on this plan was built in East Boston, Mass., in September, 1853, and opened for use in 1854, over thirty-two years ago. This dock is in use now, though it has, of course, undergone repairs, some extensive in their nature, one being to deepen it five feet. Two other docks of a larger size were built in the same place in 1855 and 1864. Since the completion of these docks others upon the same plan, with improvements from time to time, have been constructed by Simpson & Sons at Portland, Me., in 1866; in the Erie Basin, Brooklyn, N. Y.; at Cramp's shipbuilding yards, Philadelphia, Pa., in 1875; at Locust Point, Baltimore, Md., in 1880; at Harlan & Hollingsworth's shipyard, Wilmington, Del.; and, finally, at St. John's, Newfoundland, the largest and most recent of all was finished in 1884. It is also stated that a dock of 600 feet in length is to be built at Newport News, Va., for the railroad company having a terminus at that point.

SIMPSON'S IMPROVED DRY DOCK, BALTIMORE, MD., WHILE IN COURSE OF CONSTRUCTION.

The largest dry-dock on this continent is the timber dry-dock built by the Simpsons at St. John's, Newfoundland, for the Colonial Government. It is one that will accommodate any merchant vessel now afloat except the Great Eastern. Its dimensions are: Greatest length on coping (head to outer gate-sill), 610 feet 10 inches; greatest width of body on coping, 132 feet 6 inches; least width of entrance on coping, 84 feet 9 inches; length on keel-blocking, 563 feet, and greatest draught of water over sill, 25 feet. This dock is similar in shape and construction, in general details, to the other large wooden graving-docks of later construction in the United States, and a description of its construction will answer for all.

A coffer-dam was first built outside the proposed work; the excavation was then made after the enclosed site (which was only partially bare at low water) had been pumped dry. The foundation of the dock consists of wooden (spruce) piles, excepting the floor in this particular dock, which rests upon a bed of Portland-cement concrete varying from 2½ to 6 feet in thickness, which in turn rests upon a compacted, slaty gravel immediately overlying the bed-rock. Iron tubes were inserted in the gravel along the floor in a vertical position on each side near the axis of the dock and built in the concrete, with their upper ends left exposed above the surface, in order to drain any water that should happen to be in the substratum. Longitudinal timbers of yellow pine about 3 feet apart were imbedded in the concrete floor-foundation and anchored to it by iron bars and bolts. Upon these were laid floor timbers, which are covered in turn by spruce planking to form the working floor. Keel-blocks and sliding bilge-blocks are secured to the floor timbers. Provision was made also for open drains on each side of the keel-way under the floor timbers leading to the pump-well at the lower end.

The sides and head of the dock are built on a slope of 54° outward from the vertical. Six rows of piles were driven around the sides and head. Upon these piles are supported inclined heavy brace timbers of yellow pine running from the bottom of the dock to the top, and abutting upon the floor timbers at the lower end. These timbers form the skeleton, as it were, of the dock. At the upper ends these brace timbers are secured to a system of cross-caps or stringers 2 feet beneath the surface, extending back 30 feet from the coping, and supported by six rows of piles, to which the caps are firmly secured. This prevents spreading. Diagonal timbers are also introduced to tie these two systems of braces, cross-caps, and piles together. The

altars or steps of the dock are sawn out of square timber, a diagonal cut making two altars, the cut side being secured to the inclined brace timbers forming the skeleton of the dock; these altars when thus bolted forming a broad stair or treadway the entire length of the docks on both sides, by which the floor of the dock is readily reached from any point on the coping. The space behind the altars, as the sides are built up, is carefully filled in with clay from the excavation, and the filling well compacted by ramming. Around the entire dock and immediately outside of the outer row of piles supporting the cross-cap timbers a line of 5-inch tongued and grooved spruce sheet piling is driven to exclude the passage of tide-water.

The gate sills are of oak, the entrance being of timber sides sloping about 30°; the sides and floor of the entrance being built of solid yellow pine timber in two thicknesses, laid to break joints and filled in behind and underneath with concrete. To the outside faces of the sill are secured rubber gaskets, by means of which the gate joint is made water-tight. No groove is necessary for the iron caisson or floating gate, which is of the usual type, it bearing directly against the sill and solid timber of the abutment, being kept in place by the pressure of the water outside, and the joints water-tight by the rubber gasket.

The dock is filled by eight sluice-gates in the caisson, controlled by suitable valves and emptied in the usual way by steam pumps.

This dock, the largest in America, was constructed and opened for use within nineteen months from the date of commencement. Its cost was $550,000. It is but fair to state that the site was a favorable one for excavation, and that special privileges for importing machinery, etc., free of duty were granted to the contractors.

The Erie Basin dry-docks, two in number, one of them the largest on the Atlantic coast of the United States, have some points of difference from the St. John's dock. The principal point of difference is that the sides from high-water level to the top of coping are built of concrete in a monolithic form, faced with a patent artificial stone; this includes the five upper altars. This space is that most exposed to decay, and which first requires repair.

To show the rapidity with which this dock may be constructed, the dock built for the Cramps at Philadelphia may be instanced. This is 450 feet in length over all, cost $300,000, and was built in nine months.

The granite and concrete dry-dock at the Navy Yard, Mare Island,

has cost to date, in round numbers, $2,500,000, and has been in course of construction for twelve years. It is now in condition for use, but it is estimated that it will take $150,000 in money and one year in time to finish the facing and the surroundings. It is but just to say that irregular appropriations and day's work are, to some extent, responsible for this, but those obstacles and increased expenditures are just such ones as will be likely to be met with again in a similar case.

For this sum of money three timber dry-docks of the same size could be built by contract in two years, the timber dry-docks having all the advantages of stone excavated docks excepting permanence, and with the following points of superiority confidently claimed:

1st. That they are dryer and consequently more comfortable and healthy for the workmen.

2d. That wooden docks are cooler in summer and warmer in winter than those of stone.

3d. That the facilities afforded workmen by the low and narrow altars are superior to those of existing stone docks, and that the form of the altars avoids all cutting of shores.

4th. That the annual cost of repairs is less than for a stone dock in a northern climate.

5th. That even if the timber face of the dock should decay and require renewal every twenty years, the interest on the saving in first cost would be much more than sufficient to meet this contingency.

6th. That a wooden dock by contract can be built at a cost of one-half to one-third that of a stone structure of similar size.

As an example of the cost of repairs, the Boston dry-docks have been quoted before; and as improvements have been made in the construction of these docks, it may be fair to state that the largest and last built, No. 1, in 1864, was reported in 1886 by its owners to have cost but $5000 for repairs since its completion. I may add that there is no danger of the teredo injuring the dock inside, as all sea-worms require a constant supply of salt water to keep them alive, and the outside entrance-walls should be made of stone or concrete. As an extreme case of the repairs to a stone dry-dock, I will quote the case of the New York dock, which will be closed for several months and have repairs made to it at an expenditure of $100,000.

In closing this brief description of the Simpson system of docks and their advantages, it is considered not out of place to quote the following from the last annual report of the Chief of Bureau of Yards and Docks, who is to be congratulated upon his success in adding to the docking facilities of the naval service:

"Our own experience, as well as that of all other naval and maritime countries, places beyond reasonable dispute the superiority of excavated dry-docks over any other means of docking, and the greater cost and length of time formerly required in building these docks have been very materially reduced in the wooden dry-docks on the Simpson plan, which have been successfully in use in several ports on the Atlantic coast for a number of years.

I would submit, as a matter for your consideration, the question of the advisability of providing dry-docks at comparatively remote places which are frequented by merchant shipping, for the use of the Navy in combination with the merchant marine.

Such places as Puget Sound, in the extreme Northwest, and Pensacola, on the Gulf of Mexico, would be cases in point where timber for wooden dry-docks abounds and where no facilities for docking exist.

In addition, these docks would add greatly to the resources and facilities for the naval defense of these waters in time of war. At present there are no large dry-docks in the United States nearer Pensacola than Norfolk, Va., and nearer Puget Sound than San Francisco. The means for accomplishing this can readily be effected either by the construction and maintenance of these docks by this Department, charging moderate dues for docking merchant vessels, or by assisting private parties by advance of money or grants of land, with the conditions that Government vessels be docked free of cost forever, and that the United States have control in time of war or of certain emergencies.

A precedent for the latter plan has already been established in other countries, and recently in the United States by the grant of Government land in Baltimore to a dry-dock company upon the condition that all Government vessels be docked free of charge."

U. S. NAVAL INSTITUTE, NEWPORT BRANCH.
FEBRUARY, 1887.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XIII.

It is admitted that among the methods proposed for the estimation of the nitrogen contents of nitrates or nitric esters, the speediest and most accurate is that which is based upon Crum's reaction, *i. e.* by shaking with an excess of sulphuric acid and mercury and measuring the nitrogen oxides evolved. It will be generally admitted also that the most convenient and accurate means of applying this method, especially for fluids, or for substances easily soluble in water, is found in the nitrometer described by Lunge.† This instrument is now generally made use of for testing nitroglycerine in the factories, and likewise for the analysis of the various kinds of dynamite.

For the direct analysis of explosives which contain nitroglycerine mixed with other bodies, such as nitrocellulose and the like, other means were considered necessary, for the bodies could not be dissolved, and so gotten into the nitrometer. In order to use the Crum reaction with these bodies, W. Hempel‡ constructed another form of nitrometer. Hampe,§ in an extended discussion of nitrometric methods, pronounces the Hempel method convenient, easily performed, and very exact for all bodies which evolve nitrogen oxide

*As it is proposed to continue these Notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars. Address Torpedo Station, Newport, R. I.

†Ding. Poly. Jour. **228**, 447, 1878; **231**, 522, 1879; **243**, 421, 1882; **258**, 361, 1885.

‡Zeitschrift für Anal. Chem. 82; 1881.

§Ueber die Analyse der Sprengkörper, 18; 1883.

exclusively. Partly in order to be able to analyze bodies containing carbon dioxide, and partly on account of the expensiveness of Hempel's instrument, Hampe devised another method, which depends upon the fact that the nitrogen oxide evolved by the Crum reaction is converted into nitric acid by means of oxygen and hydrogen dioxide, and that this acid is then nitrated with a normal soda solution, thus following the analogous method of Schloesing for the estimation of nitrogen by ferrous chloride, which is now almost entirely abandoned for the gasometric method. The Hampe method does not appear to be employed to any extent—Lunge not having found it in use in a single factory visited—probably on account of its indirectness. When, as is often the case with a new dynamite, it is necessary, for complete analysis, to separate the soluble inorganic nitrates from the esters (nitrocellulose and nitroglycerine) by extraction, then the Lunge method is still the simplest and most convenient. Only in direct analyses of guhr-dynamites and pyroxylins has it appeared that the Hempel, or perhaps the Hampe, method was to be preferred.

A recent discussion of these methods has been published by Lubarsch,* who disputes the assertion that Hempel's nitrometer is convenient and easy of use; on the contrary, to attain correct results with it requires unremitting necessity for the quickest possible work in the introduction of the substance into the evolution chamber, while great skill and experience are required in filling the latter with mercury. Its use also includes no less than three sources of error—viz.: loss of material during solution; loss of nitrogen oxide while charging the vessels, and finally loss from the air-bubbles unavoidably present. For porous gun-cotton especially the process is hardly feasible. For explosives containing carbonic acid it is unsuitable in principle. Lubarsch considers Hampe's method too indirect for practical use. On this account he has devised an instrument which he calls a "reversion nitrometer." Lunge urges that this instrument is a step backward, as mercury must be added or withdrawn from the apparatus to get the desired quantity; the diameters of the two tubes are unlike, and hence the meniscus depressions are unequal; the use of a carbon-dioxide generator is onerous, and the neutralization of the lime in the gun-cotton unlikely to take place uniformly; while the cost of the instrument is 50 M., as against 13 M. for Lunge's.

Lunge has now made an addition to his nitrometer by which he claims to have secured all the advantages of Hempel's and Lubarsch's

* Programm des Friedrich's-Realgymnasiums, Gartner's Verlag, Berlin, 1885.

instruments at almost no expense, while maintaining the superiority for simplicity and readiness of use which his instrument has heretofore possessed. This addition consists of a thistle tube, whose stem is bent twice and then inserted in a rubber cork, which fits the funnel of the nitrometer. In use, as much of the substance to be tested is weighed out as the capacity of the nitrometer calls for (50, 100 or 140 cm.^{3}), and this, whether kieselguhr-dynamite, pyroxylins, etc., is placed in the funnel of the nitrometer. Then the rubber stopper and doubly bent thistle tube are inserted, and from 2 to 3 cm.^{3} of concentrated H_2SO_4 are poured in the thistle. Naturally some of the acid remains in the bend of the tube and seals it, thus preventing the nitrogen oxides liberated during solution from escaping. When the solution is completed the three-way cock is opened and the fluid is drawn down into the measuring tube. Of course the acid in the bent thistle is drawn down with the fluid, and it serves the purpose also of rinsing the tube. The rubber cork and thistle tube are now removed and the second rinsing is effected directly in the funnel. The analysis is now carried on as usual, and when completed the liquid is forced back into the funnel. It has never yet occurred that the cock has been obstructed by the kieselguhr mixed in the acid, though such difficulty might have been apprehended. It is clear that the carbonic acid present would, under these conditions, cause no error.

To show how good the results by this method are, Lunge cites those obtained by B. Lee, chemist to the dynamite factory at Isleton, Uri, Switzerland. He examined collodion gun-cotton which had been dried first at 40° C. and finally over H_2SO_4. In Experiment I. the funnel of the nitrometer remained closed during the entire operation—that is, the H_2SO_4 for the rinsing, as well as that for the solution of the gun-cotton, was poured through the double-bent thistle tube. In Experiments II. and III., on the other hand, the dust on the sides of the funnel of the nitrometer was washed down with a little acid, and only after this were the rubber stopper and thistle inserted and the principal part of the acid run in. After the gun-cotton was dissolved and the solution drawn into the nitrometer the stopper and thistle tube were again removed and the rinsing carried on with uncovered funnel. The latter, therefore, only remained covered while the gun-cotton was dissolving, which was from three-quarters to one hour, the solution being accelerated by gentle shaking from time to time. During solution there was a considerable evolution of colorless gas-bubbles, due, apparently, to the decomposition of the carbonates contained

in the gun-cotton. As this decomposition takes place outside of the measuring tube, the CO_2 cannot cause an error in the measurement of the nitrogen oxides, as is the case when Hempel's or Lubarsch's nitrometers are used. The results are as follows:

No.	Weight Gun-Cotton Used in Grams.	Vol. Gas Measured.	Barometer.	Thermometer.	Nitrogen per cent.
I.	0.5252	113.1 cm.³	725 mm.	17°	12.09
II.	0.5159	111.3	725	18	12.07
III.	0.5120	110.3	725	18	12.05

This proves that the method is an accurate one, even in the case where it is carried out, as in II. and III., in the simplest way.

The appearance of the above communication in the *Chemischen Industrie*, 273; 1886, led G. Alberts, chemist at the Nobel dynamite factory at Avigliana, near Turin, to describe his method of manipulation. Mr. Alberts has for the past two years been making analyses of gun-cotton with a Lunge nitrometer in the following way: The specimens are dried for about two hours at 40° C., then rubbed through a fine brass sieve; then an average sample of about 10 grams is taken and dried over H_2SO_4 to constant weight. A suitable quantity of this (about 0.48 gram) is weighed out in a 10 cm.³ glass flask with ground stopper; the 140 cm.³ nitrometer is prepared in the usual way, and then about 5 cm.³ of concentrated H_2SO_4 are poured into the flask containing the gun-cotton, mixed with a platinum wire, transferred to the funnel of the nitrometer and drawn into the measuring tube as quickly as possible. The rinsing is several times effected by pouring portions of about 3 cm.³ each of concentrated H_2SO_4 into the flask and transferring as before. Finally the platinum wire and funnel are washed in the same way. The total amount of acid used is from 15 to 20 cm.³ The CO_2 present in the gun-cotton escapes during the treatment, and no development of gas has been observed in the funnel of the nitrometer. The following figures indicate the accuracy of the method:

Ash Contained in Sample.	Nitrogen Observed.	Nitrogen in Ash Free Sample.
0.86 per cent.	13.40 per cent.	13.52 per cent.
2.40	13.20	13.53
2.16	13.24	13.53
1.80	13.30	13.54
2.60	13.20	13.55

The samples analyzed all came from the same nitrating process;

the difference in the amount of ash may be due to difference of treatment after nitration.

Alberts believes this method preferable to that with the bent thistle tube just proposed by Lunge, because not more than five minutes is required for getting the gun-cotton in the measuring tube, and the whole operation is completed in one hour; while with the thistle tube much time is spent in waiting for the gun-cotton to dissolve, and, besides, the oxides of nitrogen evolved in the funnel are lost. Lunge denies this latter assertion, as the liberated oxides are redissolved by the excess of H_2SO_4 present. The time lost in waiting for solution may be avoided by pulverizing the cotton as Albert does, and allowing it to enter the measuring tube before solution is complete. This will be better than treating in a separate flask, as that requires great skill and experience to avoid loss. ("The Analysis of Explosives," G. Lunge, *Ding. Poly. Jour.* **262**, 224–229; 1886.)

We have given in these Proceedings* the heat test as applied to dynamite and analogous nitroglycerine preparations. This has now been modified as follows:

Nitroglycerine preparations from which the nitroglycerine can be extracted in the manner described below must satisfy the following test, otherwise they will not be considered as manufactured with "thoroughly purified nitroglycerine" within the terms of the license.

This test, however, though at present looked upon as the most important, as far as testing the purity of nitroglycerine is concerned, is only one of several which any given sample of nitroglycerine preparation has to satisfy in order to establish its compliance with the definition of the license.

The test, although at present accepted as regulating and defining the meaning of the term "thoroughly purified," may, nevertheless, be modified or superseded if in the opinion of the Home Office such alteration may at any time be deemed necessary.

The apparatus required is: (1.) Test tubes from 5¼ to 5½ inches long, and of such diameter that they will hold from 20 to 22 cubic centimetres of water when filled to the height of 5 inches. (2.) The test tubes to be fitted with perforated corks, which should be conical, so as to fit all the tubes equally well. The perforations hold glass rods provided with a hook of glass or platinum to hold the test paper.

* 5, 11; 1879.

(3.) The heating apparatus as prescribed with the original Government heat test.*

The test paper used is prepared as follows: 45 grains of white starch previously washed with cold water are added to 8½ ounces of distilled water; the mixture is stirred, heated to boiling and kept gently boiling for ten minutes; 15 grains of pure potassium iodide (*i. e.* which has been recrystallized from alcohol) are dissolved in 8½ ounces of distilled water. The two solutions are thoroughly mixed and allowed to get cold. Strips or sheets of white English filter paper previously washed with water and redried are dipped into the solution thus prepared and allowed to remain in it for not less than ten seconds; they are then allowed to drain and dry in a place free from laboratory fumes and dust. The upper and lower margins of the strips or sheets are cut off, and the paper is preserved in well-stoppered or corked bottles and in the dark. The dimensions of the pieces of test paper used are about $\frac{4}{10}$ inch by $\frac{8}{10}$ inch (10 mm. by 20 mm.).

The standard-tint paper is prepared by making a solution of caramel in water of such concentration that when diluted one hundred times (10 cm.^{3} made up to one litre) the test of this diluted solution equals the tint produced by the Nessler test in 1 cm.^{3} (?) of water containing 0.000075 gram of ammonia or 0.00023505 gram of chloride of anmonium. With this caramel solution lines are drawn on slips of white filter paper by means of a clean quill pen. When the marks thus produced are dry the paper is cut into pieces of the same size as the test paper previously described, in such a way that each piece has a brown line across it near the middle of its length, and only those strips are preserved in which the brown line has a breadth varying from ½ mm. to 1 mm. ($\frac{1}{50}$ of an inch to $\frac{1}{25}$ of an inch).

The apparatus required for treating the sample to be tested consists of a wide-mouthed bottle of about 6 ounces capacity to which is fitted an India-rubber stopper having two perforations. Through one of these passes a bent tube, and through the other a filtering tube. The latter should have sufficient capacity to hold about 500 grains of dynamite. Within the bottle is placed a small test tube to receive the nitroglycerine filtering through.

About 400 grains of dynamite, finely divided, are placed in the filtering tube (a small piece of cotton-wool having previously been pushed into the contracted part of the tube) and made to fit it as

* *Loc. cit.*

evenly as possible by shaking and tapping; the upper surface is smoothed by gently pressing with a wooden rammer. Water is then poured on the top of the dynamite and allowed to sink into it by its own weight until a sufficient quantity of nitroglycerine has been displaced. The bent tube may then be connected with the filtering pump, or other means of reducing the pressure in the bottle, the displacement of the nitroglycerine being thus accelerated. The nitroglycerine collects in the test tube, and the operation is stopped before the water reaches the narrow part of the filtering tube. If any water should have passed through with the nitroglycerine, it should be removed with a piece of blotting-paper, and the nitroglycerine, if necessary, filtered through a dry paper filter.

In making the heat test, the thermometer is fixed so as to be inserted through the lid of the glass globe into the water (which is to be steadily maintained at a temperature of 160° F.) to a depth of 2½ inches. Fifty grains of the nitroglycerine to be tested are weighed into a test tube in such a way as not to soil the sides of the tube. A test paper is fixed on the hook of the glass rod so that when inserted in the tube it shall be in a vertical position. A sufficient amount of a mixture of half distilled water and half glycerine is now applied to the upper edge of the test paper by means of a camel's-hair pencil, to moisten the upper half of the paper; the cork carrying the rod and paper is fixed in the test tube, and the position of the paper adjusted so that its lower edge is half-way down the tube; the latter is then inserted through one of the perforations of the cover to such a depth that the lower edge of the test paper is just above the surface of the cover. The test is complete when the faint brown line which after a time makes its appearance at the boundary line between the dry and moist part of the paper equals in tint the brown line of the standard tint paper.

The nitroglycerine under examination will be considered as "thoroughly purified," within the terms of the license, whenever the time necessary to produce the standard tint as above described is not less than fifteen minutes.

The heat test for blasting gelatine and gelatine dynamite is applied by intimately incorporating 50 grains of blasting gelatine with 100 grains of French chalk. The mixture is to be gradually introduced into a test tube of the dimensions prescribed in the dynamite heat test, with the aid of gently tapping upon the table, between the introduction of successive portions of the mixture into the tube, so that

when the tube contains all the mixture it shall be filled to the extent of 1¼ inches of its height. The test paper is then to be inserted and the heat is to be applied in the manner prescribed for the dynamite heat test, and the sample tested is to withstand exposure to 160° F. for a period of ten minutes before producing a discoloration of the test papers corresponding in tint to the standard color test which is employed for governing the results of the dynamite heat test.

The test for liquefaction of blasting gelatine and gelatine dynamite is made by cutting a cylinder from the cartridge to be tested, whose length is about equal to its diameter, the ends being cut flat. The cylinder is then to be placed on end on a flat surface, without any wrapper, and secured by a pin passing vertically through its centre. In this condition the cylinder is to be exposed for one hundred and forty-four consecutive hours (six days) to a temperature ranging from 85° to 90° F. (inclusive), and during such exposure the cylinder shall not diminish in length by more than one-fourth, and the upper cut surface shall retain its flatness and the sharpness of its edge. If the specimen to be tested be not made up in a cylindrical form, the above test is to be applied with the necessary modifications.

The test for liability to exudation of blasting gelatine and gelatine dynamite requires that there shall be no separation from the general mass of the sample to be tested of a substance of less consistency than the bulk of the remaining portion of the material under any conditions of storage, transport or use, or when the material is subjected three times in succession to alternate freezing and thawing, or when subjected to the liquefaction test hereinbefore described. (*Ann. Rept. H. M. Inspectors Explosives*, 1884; 63.)

Dingler's Polytechnisches Journal, **262**, 128–134, October, 1886, contains a valuable paper by Prof. Franz v. Rziha upon "The Mechanical Efficiency of Explosives." According to the researches of Bunsen and Schischkoff,* 1 kilo. of gunpowder develops a theoretical power of 67410 km., according to Stadler† 88157 km., and to Berthelot‡ 161500 km.; but these are all superseded by the results obtained by Roux and Sarrau.§ These latter exploded several varieties of gunpowder and other explosives in a calorimeter in the same way as

* Pogg. Annalen, **12**, 321; 1857, and Proc. Nav. Inst. **5**, 538; 1879.
† Zeit. d. oester. Ing. und Arch. **41**; 1886.
‡ Sur la Force de la Poudre, Paris, 1871.
§ Comptes rend. **77**, 138, 478; 1873.

Bunsen and Schischkoff had done, and they obtained the following results:

One Kilo. of the Explosive.						Heat Units per 425 K.	Total Theoretical Work in Km.
Blasting powder, KNO_3 62%, S 20%, C 18%,						570.2	242335
Musket	"	"	74	10.5	15.5	730.8	310590
Cannon	"	"	75	12.5	12.5	752.9	319982
Sporting	"	"	78	10	12	807.3	343102
Gun-cotton						1056.3	448927
Dynamite, nitroglycerine 75%, kieselguhr 25%,						1290.0	548250

From the value obtained for 75 per cent. dynamite we may deduce the theoretical work of one kilo. of nitroglycerine as follows (allowing six per eent. of the nitroglycerine to be consumed in heating the kieselguhr): $(548250 \times 100) \div (75-6) = 794565$ km. Again, from the values found for gun-cotton and nitroglycerine we may calculate the theoretical work of explosive gelatine composed of nitroglycerine 92 per cent. and gun-cotton eight per cent. thus: $(794565 \times 92) + (448927 \times 8) \div 100 = 766913$ km. According then to the researches of Roux and Sarrau, the four explosives principally used rank as follows:

Explosive.	Theoretical Work in Km.	Relative Value.	
Blasting powder with 62% saltpetre, ...	242335	1.00	
Dynamite with 75% nitroglycerine, ...	548250	2.26	1.00
Explosive gelatine with 92% nitroglycerine,	766913	3.16	1.40
Nitroglycerine, ...	794565	3.28	1.45

The last two columns give the relative efficiencies of these four explosives as deduced from theory. Approximately the same values have been obtained in practice in blasting. Thus experience has shown that to move one cubic metre of the same kind of rock, under precisely the same stratigraphic and other local conditions, by weight, two to three times as much blasting powder as dynamite will be required. Makuc,* director of the mines at Bleiberg, in a lengthy experience found the ratio for powder and dynamite to be as 1 : 1.84. From an extended experience in railway building, especially in the Buchberger cut, Von Pischof† found the following ratios for powder and dynamite:

*Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 227; 1882; also Ding. Poly. Jour. **246**, 186; 1882.

†Trauzl, Dynamit und Schiesswolle, 147, Vienna, 1870.

In medium hard syenite, ...	1 : 2.40
In hard syenite or granite, ...	1 : 2.57
In felsite or quartzite, ...	1 : 3.30

The mean of these four results gives a ratio of 1 : 2.53, while Roux and Sarrau find a theoretical relation of 1 : 2.26.

Experiments have given the following relations between dynamite and gelatine:

St. Gothard, railway,*	1 : 1.46
Zankeroda, mines,†	1 : 1.45
Tarnowitz, excavation,‡	1 : 1.41
Mannsfelder, excavation,§	1 : 1.33
Mean, ...	1 : 1.41

while theory requires 1 : 1.4.

In the tests by Trauzl's method, where equal weights of the explosive are exploded in cavities in lead cylinders, and the efficiency measured by the increased volume of the cavities, the following results were obtained:

Author.	Dynamite.	Gelatine.	Nitroglycerine.
V. Friese ‖ (Committee report),	1.00	1.26	
Münch,**	1.00	1.57	1.86
Trauzl,††	1.00	1.43	1.43
Dr. Klose,‡‡	1.00	1.50	1.80
Mean, ...	1.00	1.44	1.70

Here, again, we have a fairly close agreement with the theoretical values of Roux and Sarrau.

The theoretical efficiency of an explosive cannot be realized in useful work for several reasons—viz.: because of incomplete explosion; because of the compression and chemical changes induced in

* Tetmajer, Nobel'sche Präparate, 37, Zurich, 1882.

† M. Georgi, Jahrbuch für das Berg- und Hüttenwesen im König. Sachsen, 1882.

‡ Zeitschrift für das Berg-, Hütten- und Salinenwesen, 191; 1882.

§ *Ibid.* 246; 1881.

‖ Wochenschrift des oester. Ing. u. Architektenvereins, 144; 1883.

** *Ibid.* 205; 1882.

†† Trauzl, Ueber neue Sprengstoffe, 24, Berlin, 1883.

‡‡ Zeitschrift für das Berg-, Hütten- und Salinenwesen, 91; 1883.

the surrounding material; because of the energy expended in cracking * and heating † rock which is not displaced; because of the escape of considerable quantities of the gases through the blast hole and the fissures made by the explosion. In all probability the extent of this loss can never be determined by direct experiment, as the phenomenon of an explosion does not permit of close observation; nor can it be determined by comparison with the work done under other circumstances, as we are yet uncertain as to the so-called dynamic resistance of rock.

We are therefore met by a problem which for the present can only be solved by employing a technical analogy, and such a one is found in the firing from ordnance and small arms, where fortunately the work done by a powder charge has been determined with great precision. The use of the analogy is permitted because one can, according to the arrangement of the ball or tamping, shoot or blast with one and the same charge, and, therefore, with one and the same source of power, overcome resistance of two forms but of nearly equal magnitudes; and because, further, the process of burning the charge, whether in shooting or in blasting, is technically the same, for in each case the charge rests at the bottom of the cavity closed by means of the shot or tamping, and in each case the space occupied by the charge is increased through the chemical development of the gases so that the shot is moved forward in the bore or the tamping is compressed in the blast hole; and, finally, the practice of years has demonstrated that the greatest amount of useful work is realized either in shooting or blasting when certain relations of diameter, length and strength of walls on the one hand, and of size of charge on the other, have been attained.

Objections to the use of this analogy can only be based upon doubts as to whether the explosion is completed in the same time in both instances—that is, for the like release of power from the source—and whether the loss of gas is equal in both cases. These doubts are, however, so far as it is possible to observe, insufficient to prohibit the use of this analogy, since this is the only existing one, and the error connected with its use can in no case be great.

* Schell, Beobachtungen über Gesteinschwingungen in der Grube, in der Zeitschrift f. d. Berg-, Hütten- und Salinenwesen, 340; 1880, and 31; 1883; and M. Becker, Allgemeine Baukunde des Ingenieurs, 421; 1853.

† In rapid firing by artillery and infantry, from 10 to 15 per cent. of the theoretical work of the charge is spent in heating the piece.

Gen. Poncelet* states that a 12-kilo. shot thrown by a 4-kilo. charge attains an initial velocity of 500 m. per second, and calculates from this and from the work expended in the recoil of the piece that one kilo. of gunpowder develops an energy available for useful work of 38354 km.

Combes† cites the data of Poncelet, and gives in connection with it the capacity for useful work of powder as measured by the old French powder proof. This required that 92 grams of powder should throw a ball weighing 60 old French pounds = 29.37 kilos. a horizontal distance of $W = 225$ m., when the proof mortar was elevated $a = 45°$. From the initial velocity thus developed, $v = \sqrt{g W \div \sin 2a}$, and from the equation for energy, $A = Qv^2 \div 2a$, we deduce the useful mechanical work developed by the charge, $A = \frac{1}{2} Q W = \frac{1}{2} (29.37 \times 225) = 3304$ km., from which we have for one kilo. of powder $A = 3304 \div 0.092 = 35913$ km.

Since the publication of these results immense advancement has been made in the science of ordnance, not only in the construction of guns and projectiles, but also in the invention of means for observing the pressures of the gases in the bore and measurements of the velocities of the projectiles (the latter by Boulangé's‡ method), so that the capacity of gunpowder for useful work may be deduced from the results of a large number of different experiments. In the following table a variety of such experiments are given for the purpose of obtaining a mean value. These have been quoted partly from the *Handbücher*§ *für die öesterreichischen Generalstabs-Offiziere*, and partly from the *Mittheilungen des Artillerie und Genie-Wesens.*

Notwithstanding the great variety of powders used, and the great differences which existed in the relations between the length and diameter of bore, size of charge and weight of projectile, and in spite of the fact that in these experiments the weights of the charges varied from .005 to 408.6 kilos., while that of the projectiles varied from .024 to 1000 kilos., yet there is an astonishing agreement in the values obtained in the last column. The constant for the useful work is taken by ordnance officers as being at least 40 metre-tons, and hence we will use this value, 43788 kilogram-metres, in the following discussion.

* Traité de Mêcanique industrielle (Paris, 1834), 180.

† Traité de l'Exploitation des Mines (Paris, 1844); German of C. Hartmann (Weimar, 1852), 152.

‡ Dingl. Poly. Jour. **261**, 254; 1886.

§ Hauptmann Springer, Brünn, 1880.

Kind of Musket or Gun.	Weight of charge in kilos., L.	Weight of projectile in kilos., Q.	Observed initial velocity in metres, v.	Work done by charge in kilogram-metres.	Useful work per kilo. of powder $\frac{Qv^2}{2g}$ km., $\frac{Qv^2}{2gL}$.
Austrian infantry rifle, Wundl (old model)	.005	.024	440.0	232	46464
Austrian infantry rifle, Wundl (new model)	.005	.024	453.0	251	50200
Austrian 7 cm. field-gun	.350	2.900	299.0	13227	37791
" 8 "	.950	4.300	442.0	39069	41125
" 9 "	1.500	6.400	448.0	65536	43690
Krupp's armor-piercing gun (old mod.)	205.000	776.700	502.4	9992000	48700
" 40 cm. gun (1881 model)	220.200	779.000	519.4	10716000	48664
" 40 " (1884 model)	279.200	741.000	615.2	14300000	51071
French 34 cm. gun	164.000	420.000	600.0	7710000	47012
" 37 "	246.500	535.000	600.0	9821000	39842
Woolwich 23 cm. gun	149.800	172.500	728.6	5196000	34640
" 34 "	283.700	567.500	625.2	11310000	39866
Elswick 23 cm. gun	90.800	172.500	671.0	3960000	43612
" 41 "	408.600	817.000	616.1	15810000	38693
" 43 "	350.500	1000.000	558.8	15930000	45448
Mean					43788

If according to Roux and Sarrau we place the theoretical work of one kilo. of powder at 319982 km., then we may reckon that the available work, when fired in gun or musket, is $\mu = (43788 \times 100) \div 319982 = 13.71$ per cent.

In default of other data and methods of research, the useful effects of blasting charges of powder may also be placed at 13.71 per cent. The same value is also permissible for other explosives, since the foregoing discussion shows that the practical efficiency of explosives stands in the same relation as their theoretical efficiency. Consequently we have:

Explosive.	Theoretical Work, Km.	$\mu = 13.71$ gives Useful Work, Km.	The Ratios of these Values.	
Blasting powder 62% saltpetre,	242335	33224	1.0	...
Dynamite 75% nitroglycerine,	548250	75165	2.2	1.0
Explosive gelatine 92% nitroglycerine,	766913	105144	3.2	1.4
Nitroglycerine,	794565	108935	3.3	1.5

The useful work of a blasting charge is employed two ways—viz.: partly in shattering the rock and partly in throwing or displacing the shattered masses. It is a familiar engineering problem to reduce the projectile force of a blast to a minimum (though for practical reasons it cannot be wholly dispensed with) by means of suitable-sized charges,

properly located in blast holes of estimated dimensions, and so avoid the cannonading of which the workmen are so fond. With the discovery of at least approximately correct values for the useful work of charges, we are now able to demonstrate the correctness of this principle.

The volume of the shattered rock is computed by the formula $V = k \times t^3$, in which k is a coefficient determined by practice, and t is the depth of the blast hole. For example, $t = 0.75$ m. and $k = 0.8$;* then $v = 0.34\ m^3$. In a certain stone of specific gravity $= 2.8$ the weight of explosive will be $Q = 0.34 \times 2.8 \times 1000 = 952$ k.

If for simplicity it is assumed that the charges were at less than 45° and that the mass is only thrown 10 m., then the work of projection will be $A = \frac{1}{2} Q W = \frac{1}{2} (952 \times 10) = 4760$ km.

The blast acts in a hole 75 cm. deep and 30 mm. in diameter, which is charged to a depth of 20 cm. with dynamite of 1.6 sp. gr. and containing 75 per cent. of nitroglycerine. This charge weighs, therefore, $L = (7 \times 20 \times 1.6 \times 1000) \div 1000000 = 0.22$ k., and has a capacity for useful work of $a = 75165 \times 0.22 = 16536$ km. This action of projecting, then, has consumed $(84760 \times 100) \div 16536 = 29$ per cent. of the available useful work; whence it may be seen that, however general the calculation, this throwing of the *débris* is an evil, and represents a not-to-be-underestimated loss of available energy.

The *Engineering News* Publishing Co., New York, 1886, reprint from their journal the report of Capt. William H. Bixby, U. S. A., to the War Department on "New Ordnance Material in Europe," from which we extract the following account:

During the writer's visit to Magdeburg he had the opportunity of examining Gruson's new explosive of 1881,† which seems especially adapted to all military purposes wherever a safe but violent explosive is required. This explosive is composed of two ingredients which can be transported with perfect safety, are mixed only for use, and can be re-separated with ease at any subsequent moment. It is more powerful than nitroglycerine, safer than dynamite, produces no unpleasant effects upon those who handle it, and is cheap. In 1881–2 it was being tried by the German Government, but, as usual, all results were kept secret. The composition of this explosive is still kept partially secret. One ingredient is strong nitric acid, and the other

* Reiha, Lehrbuch der Tunnelbaukunst, **1**, 189, 192, 197.

† Proc. Nav. Inst. **11**, 771; 1885, and **12**, 616; 1886.

is a crystal; it is impossible to explode either alone, so that they are both perfectly safe as regards transportation. In order to make use of the explosive, the crystals are placed in the nitric acid, where they dissolve rapidly with a slight reduction of temperature; there is no chemical combination, but only a solution in this case; the mixture is then ready for use, but cannot be exploded by any ordinary method; for explosion it requires the use of a fulminating or detonating fuse twice as powerful as that used to explode dynamite. If, by any chance, after being thus prepared, the mixture is not required for immediate use, the addition of a little water dilutes the nitric acid to such an extent that the other ingredient is no longer held in solution; the crystals re-form, and can be separated by merely straining the mixture; the crystals are then dried (without the slightest danger), and are ready to be used again; the nitric acid is left in its diluted state and sold or used for other purposes. If the crystals are heated to a high degree of temperature, they burn, without explosion, somewhat like sealing-wax; neither ingredient alone, nor the mixture, can be frozen at any temperature above zero Fahrenheit. Neither the crystals nor the mixture produce any other unpleasant effects on the persons who handle them except the usual effect produced by nitric acid. The nitric acid is strong, but not fuming, yellow in color, and very pure.

The crystalline ingredient of this new explosive is Mr. Gruson's secret. It is a substance well known, to whose transportation there is no objection; it is, in fact, often transported to-day in commerce; it is not soluble in water, does not absorb water, and never becomes damp. Mr. Gruson discovered this explosive while experimenting to find some economical method for breaking up his old-iron chills. He thinks he has such facilities for its manufacture as will allow him to make it cheaper than other people.

In order to allow the use of this explosive within projectiles, Mr. Gruson manufactures two varieties of shells, each containing two compartments connected by a truncated conical opening, this opening being ordinarily filled by a solid conical plug. The liquid nitric acid is placed in the cavity on the side of the larger base of this conical plug, the cavity being lined with glass; the crystalline ingredient is placed in the other cavity on the side of the smaller base of the conical plug. If the shell is desired to explode when the shot strikes, the shell is made to contain at its forward end a percussion fuse opening into the first cavity containing the crystalline powder;

the conical opening above described connects this first cavity to the second cavity containing the nitric acid within its thin glass case, the conical opening being so placed that its plug has its larger base toward the rear of the projectile. When the gun is fired, inertia forces the conical plug out from its cavity into the compartment containing the nitric acid, and the two compartments of the explosives are mixed thoroughly by the rotation of the shell during its flight. The explosive is then ready to be exploded by the percussion fuse at the moment that the shot strikes any resisting object. In other shells, where it is desired that the shot should explode at a certain time after striking, the shot contains at its rear a chemical fuse connecting with the cavity containing the crystalline powder; in front of this latter is the compartment containing the nitric acid within its glass envelope; the conical opening connecting the two compartments is placed with the larger base of the conical plug turned toward the front, so that the plug cannot be disturbed from its position by any sudden forward movement of the projectile. When the shot strikes, the plug and the crystalline powder in its rear are driven by their inertia into the nitric acid; the whole is thus thoroughly mixed; the time chemical fuse, broken by the shock of striking, will cause the explosion of the whole mixture at the end of any given desired interval thereafter. In the latest model of these explosive shells, the glass case containing the nitric acid is cemented to the interior of another case of thin wrought iron. The latter can be introduced within the projectile when desired.

The percussion shells have been fired at long ranges, so as to land in ordinary hard ground. The explosion was so violent that the pieces of the shell flew rapidly in all directions, backward almost as far as forward, thus showing the intensity of the explosion. Such shells, exploding behind the interior crest of a parapet, would destroy material behind this parapet and would injure men who might consider themselves secure because they were sheltered from direct fire.

This explosive has been tested by blows from a pile-driver, in order to see how liable it is to explode under percussion. A weight of 112 kilograms (246 pounds) falling one metre broke the case of the fuse without producing explosion; falling three metres, it still failed to produce explosion.

Two examples may be quoted to show the strength of the explosion: First, a chilled-iron cylinder of 30 inches diameter was torn all to pieces by the powder which filled an 0.8-inch hole along its axis.

Second, one kilogram of the explosive was placed in a cast-iron shell of 75 pounds weight and exploded; the explosion tore the shell all to pieces in such a way that 240 of its fragments weighed in all only 37 pounds; the rest of the fragments were not to be found.

On the 29th November, 1881, the writer witnessed some experiments with this new explosive. The solid component looked like brown sugar, except that the crystals were needle-like, and nearly an eighth of an inch in length. When these crystals were placed in the flame of a Bunsen burner, they burnt slowly, in much the same way as sugar or sealing-wax, and with a good deal of smoke. Some of the crystals were put on an anvil and hammered without explosion. The crystals were then put into strong, but not fuming, nitric acid and were immediately dissolved. A few drops of the solution were put on the anvil and hammered without exploding. A piece of paper dipped in the solution was put in the flame of a Bunsen burner and burned in about the same way as the crystals had burned. A piece of paper put into the solution so as to serve as a wick was then ignited, and burned with increased flame, but without igniting the solution. Water was then poured into the solution, and the solid component recrystallized into white, flaky crystals. This recrystallization was accompanied by a slight *reduction* in temperature, hardly sufficient to be noticeable to the touch. Some of the explosive mixture was then placed in a thin metal tube in the ground outside the building and exploded by the use of a friction primer of triple the strength ordinarily used for exploding dynamite; the explosion produced a very effective result. The brown crystals were said to be poisonous if eaten, but not poisonous to produce any bad effects if simply tasted or handled. An actual test showed the writer that they were slightly astringent, with something of the taste of quinine.

Captain Piorkowski, Mr. Gruson's representative, was at Berlin on the 18th of November, 1881. On his return, he stated that the Prussian Government were going to continue experiments with the new Gruson explosive at Graudentz. The explosive does not yet work regularly enough, as it explodes sometimes one second only, and sometimes as much as ten seconds after impact. Mr. Gruson would like to have some other government besides Prussia experiment with this explosive, especially some government that would be willing to publish the results of its tests. He would not be willing, however, to make known the composition of the explosive unless in some way he could be first guaranteed a royalty or other compensation for the

use of the powder, if it should prove to be what he claims for it. For a similar reason he is not willing to furnish a sample of the crystalline powder, because it might be analyzed and the secret of the explosive discovered. He would be willing to send an agent to the United States or any foreign country to exhibit the explosive, in case that there was any possibility of selling the explosive, or obtaining a royalty for its use. He would be willing to sell anybody the use of this powder, and the right to manufacture it, but only in consideration of a cash sum payable immediately, or a royalty during a term of about 15 years. He estimates that the strength of this explosive is 1.3 times as powerful as nitroglycerine, and that the cost would be about 25 cents a pound, or less.

Another explosive, tested in France, has been brought to the writer's notice. This explosive is the invention of M. Michalowski, and is called "miner's powder." It is powerful, easily made, easily and safely handled and transported, and is well adapted to many military operations. This powder was lately investigated by the Society of Mineral Industry at Saint Etienne, France.* As a result of a series of experiments, the committee reported, in substance, as follows:

According to the wording of the patent the composition of the powder is:

Potassium chlorate, ...	50
Binoxide of manganese, ...	5
Organic matter, finely pulverized, ...	45
	100

The organic matter which forms the combustible element of the explosive mass should be wood sawdust, powdered tan, bran, etc.

The committee concluded their report as follows:

1. That the miner's powder was manufactured without danger, in the most simple manner; it was only required to add bran to a solution of chlorate of potash and leave it to dry.

2. That its transportation should be attended with no difficulties, for it was only after some effort that the particles were exploded upon an anvil.

3. That the force of the powder is practically equal to dynamite No. 1.

* Engineering News, **90**, Feb. 23, 1884.

4. That the gases produced by its explosion are probably much less injurious than those emanating from other explosives.

5. That this powder can be firmly compressed by rammers without danger, provided no sparks are evolved.

Still a third of these safe but violent explosives, available for many military operations, "ammonia-nitrate powder," has been brought to the writer's notice. In this explosive, ammonium nitrate forms the principal ingredient. This explosive was not tested in the writer's presence, but was said to be as powerful as dynamite, to fuse, but not to burn, in the presence of a flame, and to be exploded with difficulty under the blow of a hammer. This powder is said to be composed of:

Ammonium nitrate,	80
Potassium chlorate,	5
Nitro-glucose,	10
Coal tar,	5
	100

The explosion of this powder requires the use of a 10-grain fulminating cap.

Captain Bixby also states that the French Government have been experimenting with the use of celluloid for a waterproof covering of powder-cases. A rough wooden box was painted inside with one coating of celluloid. It was then filled with nitric acid and left for 24 hours. When then examined, the wood was found to be entirely untouched by the nitric acid. It is thought that the celluloid will prove so excellent a waterproofing for powder-cans and cases, that there will be no further trouble in keeping powder dry, even in the dampest localities.

He notes also the method for covering floors and other surfaces of magazines with "cork paint" as practised in England, and describes Cohausen's psychroscope for determining the relative hygrometric conditions of the external and internal atmospheres of the magazine.

The *Scientific American*, **56**, 101, Feb. 12, 1887, reprints from *Industries* an article entitled "Recent Progress in the Manufacture of Explosives," in which it says: "The various explosives now manufactured and known under the names of dynamite, sebastine, extra dynamite, petrolite, nitrolite, and possibly many others, consist of

nitroglycerine mixed with different proportions of solid materials, such as charcoal, gun-cotton, nitrate of potash, and different kinds of porous earth and clay. All these compounds have given rise to numerous accidents by reason of their spontaneously explosive nature. Many other nitro-compounds besides nitroglycerine have been suggested as explosive agents. Among these may be mentioned nitro-benzole, nitro-toluol, nitro-naphthaline, nitro-phenol, nitro-mannite, and the compounds obtained from starch, cellulose and sugar by the action of concentrated nitric acid.

"A German patent (No. 36,872) of Alfred Nobel, in Paris, covers the use of a mixture of metallic salts of acids rich in oxygen, *e. g.* nitrate, chlorate, or perchlorate, with one of the nitro-compounds of glycerine, sugar or cellulose. The barium, potassium and sodium salts are mentioned in the patent, and for blasting operations a mixture of from 75 to 80 per cent. of one of these salts, with 20 or 25 per cent. of nitroglycerine, is recommended. For firearms, 5 to 15 per cent. of nitroglycerine is added, or 10 to 30 per cent. of either nitroglycerine thickened with nitro-cellulose, or nitro-sugar, or nitro-cellulose alone, is substituted. These mixtures are said to be safe, and not liable to spontaneous combustion or explosion.

"A somewhat similar mixture has been patented by Jacob Engels, of Kalk, near Deutz (Nos. 36,705 and 10,232), in which the nitrate, sulphate, or chloride of ammonium is the salt added to the nitro-compounds. The composition of these explosives is somewhat complicated. They contain 5 to 10 per cent. pyroxyline, 70 to 60 nitroglycerine, 15.5 to 18 pyro-papier, 0.5 nitro-starch, 5 to 1 nitro-mannite, 0.5 nitro-benzole, 10 to 30 ammonium salts, 0.5 water-glass, and 8 to 10 of saltpetre. An explosive based on the same principle, and recommended for shells, is made from gun-cotton saturated with a solution of potassium chlorate (100 parts gun-cotton to 12 parts potassium chlorate), and then slowly dried at a temperature of from 62° C. to 75° C.

"The shells are filled with this compound by first making it into a paste with collodion (12 to 14 per cent.) and then allowing the mass to harden in the shell. This mixture is also said to be capable of withstanding a sudden shock without explosion. The double picrate of sodium and lead or barium obtained by mixing three equivalents of sodium picrate with one of lead or barium picrate is also the subject of another patent. The explosives in which these picrates are used have the composition: 15 to 30 per cent. barium sodium picrate,

8 to 30 lead sodium picrate, 2 to 10 potassium picrate, 20 to 5 nitronaphthaline, 40 to 20 potassium nitrate, 3 to 1½ sugar, 3 to 2 gum, and 4 to ½ of lampblack (English patent 14,140).

"M. Carl Lamm, the director of the manufactory of explosives at Stockholm, has come to the conclusion that one of the safest explosives consists of a mixture of nitrate of ammonium with a di- or trinitrobenzine. The dinitrobenzines are easily obtained from benzine by direct nitration with a mixture of nitric and sulphuric acids. All three compounds are thus formed, the meta compound being in the largest quantity. They are all soluble in alcohol, from which solution, on cooling, the meta compound crystallizes out first, while the ortho- and para-dinitrobenzoles remain in the solution. The meta compound melts at 90°, and, when free from nitric acid, can be kept unchanged for any length of time. The trinitro compound is easily obtained from the meta compound by heating it with more nitric acid and fuming sulphuric acid to 140° C. Numerous experiments have been conducted by M. Lamm with a view to ascertaining the best proportions of these two substances to yield the maximum explosive effect. He has named this mixture 'bellite,' and recommends its use as a substitute for the coarser kinds of gunpowder used in the larger firearms.

"Bellite has the important quality of not being spontaneously explosive; it can, therefore, be manipulated and transported without any risk. To cause it to explode, it is necessary to bring it into contact with a flame or with some substance that is strongly heated. Numerous experiments have been tried in order to determine whether it is possible to explode it by a violent shock; but in the two years during which these experiments have been carried on it has never been made to explode by a shock alone, or by friction. Both dinitrobenzine and ammonium nitrate are stable compounds, if in their preparation care be taken that there remains no excess of free nitric acid. P. J. Cleve, the well-known professor of chemistry in the Swedish University at Upsala, has confirmed these statements of the discoverer, and has certified that bellite may be stored, or transported by railway, without any danger of spontaneous explosion.

"Bellite appears to have a power which is greater than that of any of the explosives at present employed. In one experiment 15 grams exploded by means of an ordinary fulminating cap, projected a shell weighing 42.5 kilos. to a distance of 120 metres; and in experiments in blasting, bellite has been found to remove a greater quantity of

rock than that obtained by employing the same weight of explosives derived from nitroglycerine. The mean force of bellite is equal to thirty-five times that of ordinary cannon powder.

"The Swedish artillery have made a series of experiments with this new explosive that go to prove that when it is used for grenades, these grenades are not liable to spontaneous explosion by any sudden shock, and that when thrown and caused to explode by a convenient percussion fuse, the results are superior to those obtained from grenades charged in the ordinary way with powder. Mines constructed with bellite are not set on fire or exploded even when struck by a bullet.

"The explosive force of bellite, compared with that of fulminating cotton, is as 115 to 100. From these results it would appear that bellite marks a new departure in the history of the manufacture of explosive materials; and it would appear that from its valuable property of being incapable of explosion by shock or friction, we may not fear its application to the destruction of property in the same way that dynamite has unfortunately been used. M. Henry D'Estrey has lately brought this compound under the notice of the scientific public of France, so that we may hope that before long it may come into general use as a substitute for dynamite and the allied nitroglycerine compounds.

"Recent experiments by the Minister of War at Berlin on new explosive materials have just been conducted at the island of Eiswerder, near Spandau, and if this compound has been included in their investigations, we may hope for further particulars of its properties in the report on the results."

The *Rev. Mar. et Col.* **91,** 589; 1886, states that M. Ruckstchell, a Russian engineer, has invented a new explosive which he calls Silotvaar. From experiments made at Camp Krasnoie Silo, near St. Petersburg, the new powder possesses a penetrative force ten times superior to that of ordinary cannon powder. Its explosion produces neither fumes nor smoke, and is not attended with any detonation. It is said, too, that a motive force can be produced from this explosive and operated by a motor invented by M. Ruckstchell which is superior to gas or vapor.

The London *Telegraph* announces the discovery of a substitute for gunpowder, primarily intended to replace the gunpowder used on

the stage. The accidents which have happened to actors from the discharge of firearms are so frequent that any means of preventing them would be a boon to the profession. M. Edouard Phillippe, the inventor, showed the adaptability of his invention to the chassepot, the *fusil gras*, to old musketoons, revolvers, and for toy pistols made of wood. The explosive, fired at six paces, left no trace on a sheet of white paper; whereas the plug from an ordinary stage musket left at that distance an ugly black mark. The substance used by M. Phillippe consists chiefly of phosphorus, and, the cartridge being exceedingly thin, the whole charge completely disappears. No trace of it is to be found. The detonation, on the other hand, is as loud as that produced by gunpowder, the flame as vivid and the smoke apparently as dense, but it has the advantage of having no smell.

Appleton's Annual Cyclopædia for 1885, 342–347, contains a well-edited article on "Explosives," by Marcus Benjamin, Ph. B.

"Notes on Experiments with High Explosives," by M. M. Macomb, 1st Lieutenant 4th Artillery, U. S. Artillery School, 1886, is the title of a work of some 17 pages, with plates, which contains a detailed account of upwards of 50 experiments in which dynamite, atlas powder, forcite, explosive gelatine, rackarock and tonite were employed in destroying structures, disabling guns and gun-carriages, and breaching fortifications. There is nothing new either in the experiments or the results (though it is always wise to place such results on record), but, if this represents the course of instruction at the Artillery School, it is an eminently practical and useful course.

The *Professional Papers of the Engineer School of Application, U. S. A.*, **2**, 1–121; 1885 (?), contains a translation of the "Report upon Trials with Submarine Mines Executed Jointly by Sweden, Norway and Denmark, 1874–1876," made by C. W. E. Oxholm, C. E., Asst. Eng. Willet's Point. This translation is somewhat fuller than that published in *Proc. Nav. Inst.* **7**, 121–154; 1881.

E. Bernard et Cie., of Paris, have published "Les Explosifs modernes," by Paul F. Chalon, one volume, 420 pp., with 161 figures. Spineux et Cie., of Brussels, announce the second edition of "Matériel de Guerre de nos Jours," by N. Adtz. The *Bibliotheca Historico-Naturalis* notices "La Poudre à Canon," by M. Hélène, Paris, 1886.

PROFESSIONAL NOTES.

EXTRACTS FROM AN ARTICLE ON THE PROTECTION OF HEAVY GUNS FOR COAST DEFENSE.

By Captain G. S. Clarke, R. E.

Published in the Proceedings of the Royal Artillery Institution, Woolwich, February, 1887.

The whole question of the choice of modes of protection will be found, on consideration, to be closely bound up with the views which may be taken as to—

1. The probable accuracy of the fire of ships.
2. The probable effect of shrapnel and common shell.
3. The probable effect of the fire of machine and quick-firing guns.

In adopting the barbette, open battery with embrasures, or the disappearing principle, certain risks are obviously accepted. Is it worth while for the sake of some great advantages to accept these risks? To this very important question different answers will doubtless be forthcoming, since few will agree on the measure of the risk, and the three points above mentioned admit—even court—much speculation. If a ship can, at frequent intervals, hit a barbette gun, or plant a shell fairly in the neck of an embrasure at moderate ranges; if every heavy shell which strikes near the exterior crest of a parapet will plough its way through and burst in the battery, barbettes and embrasures stand condemned. If the ship can drop the bullets of heavy shrapnel at a considerable angle of descent over the crest of a battery, overhead cover of some sort is universally indispensable. If she can, with reasonable certainty, throw common shell which, striking a little short of the crest at a descending angle, blow in the retaining wall on the gun and detachment, iron protection in some form would seem to be inevitable. If, guided by a momentarily defined smoke-puff, she is easily able to land shells on an invisible target, the range of which cannot be exactly ascertained, the disappearing principle becomes questionable. Finally, if the ship cannot do these things now, is there any reasonable probability that she will shortly be able to do so? Here is evidently a wide field for speculation. The record of ship's practice cannot be kept like a rifle-shooting register. Experimental firing against targets representing shore batteries is excessively rare. We have practically only the experience of Alexandria on which to build, and the easy victory obtained by the ships makes it all the less likely that the lessons of the action will ever receive serious attention.

There are some essential differences between a naval attack on shore defenses now and at the time of Algiers. Then the vessel enormously outmatched the shore batteries. A first-rate ship, with 66 guns to her broadside, was superior to almost any single battery. A fleet was immensely superior to a fortress. Where the shore works were open the ships could pour in an almost continuous hail of shot and shell. There was room for plenty of bad shooting, and yet there would be plenty of hitting, while the continuity of fire was demoralizing in the extreme.* Even in much later days the United States fleet

*Even thus the ships did not invariably show a marked superiority over coast works unless the ranges were short. Such facts as the following are not without significance at the present day: In July, 1806, Sir Sidney Smith," with the Pompée, an 80-gun ship; the Hydra, Captain Munday, and

poured 45,000 shot and shell into Fort Fisher in two successive bombardments, the rate of fire on the first occasion being given as 115 projectiles per minute. It is not surprising that the return fire was very ineffective and soon practically ceased. In the days of wooden ships the ranges were comparatively short.* At Acre the ships were quietly allowed to take up their assigned stations at from 600 to 700 yards from the defenses "before a shot was fired from the garrison." This was an advantage, inasmuch as the details of the work attacked could be well made out, the damage being inflicted was better seen, and the fire could be better directed. Moreover, mines and fast torpedo boats were non-existent, and if a ship could be laid alongside a shore battery—a course our naval commanders always strove to adopt†—she could crush the latter by sheer superiority of metal and rapidity of fire.

Conditions are now completely changed. The single ship will rarely outmatch the modern first-line battery. The fortress will far more nearly approach the fleet in weight of metal. Thus the Dupérré carries only four 46-ton guns in her barbettes, and 14 broadside 5½-inch guns. The Inflexible has but four 80-ton guns and eight 20-pounders. It is doubtful if these two ships together would be a match for the six turrets of Fort Milutine at Kronstadt. The whole fleet engaged at Alexandria opposed 80 heavy guns to 36 on shore; but, on the one hand, the shore guns could not all be simultaneously employed, while on the other hand the actual gun power of the broadside ironclads must be halved. Compare the broadsides of the Inflexible and an old three-decker. With four 80-ton guns and four 20-pounders, the former ship can deliver 6880 pounds of iron at a single discharge. With 48 32-pounders, 17 8-inch guns and one 68-pounder, the latter delivered 2556 pounds. The 80-ton guns take five minutes to load, and the 20-pounders perhaps half a minute, the broadside of smooth-bores about one minute. Thus in five minutes the Inflexible fires 7600 pounds of iron, the wooden ship 12,780. The total *number* of projectiles in this time is, for the Inflexible 44, and for the wooden ship 330. Dealt with in this way, figures are not, perhaps, particularly valuable, and the above estimate is highly favorable to the Inflexible, since the 20-pounder of to-day possesses much less relative value than the old 32-pounder, and would have little chance of disabling a properly mounted heavy gun, while the Inflexible's 20-pounders could not be served in face of moderately accurate shrapnel or machine-gun fire from the shore. Omitting them, the proportionate rate of fire between the two ships is as 1 : 82.5.‡ In any case the importance of individual rounds is now enormously increased, but it may fairly be doubted whether the possible destructive effect of a single projectile on well-designed works has been materially augmented. It is conceivable that a single lucky 8-inch spherical shell might have dismounted a single shore gun and killed or wounded all its detachment. A 16-inch rifle shell can do no more in a properly traversed battery, may even effect less, since a modern gun and its carriage is a very substantial traverse against splinters, while it is open to question

another frigate, anchored about 800 yards from a battery of two guns, situated on the extremity of Cape Licosa, and protected from assault by a tower in which were 25 French soldiers." "The line-of-battle ship and the frigate fired successive broadsides till their ammunition was nearly expended, the battery continually replying withs low but destructive effect. The Pompée, at which ship alone it directed its fire, had about 40 shot in her hull; her mizzen topmast carried away; a lieutenant (Slessor), a midshipman, and five men killed, and 30 men wounded. At length, force proving ineffectual, negotiation was resorted to, and after some hours' parley, the officer . . . . capitulated. It then appeared that the carriage of one of the two guns had failed on the second shot, and the gun had subsequently been fired lying on the sill of the embrasure, so that in fact the attack of an 80-gun ship and two frigates had been resisted by a single piece of ordnance."—*Journal of Sieges in Spain, Major-General Sir J. Jones, R. E.*

* At Copenhagen it was a matter of complaint that the pilots would not accept the responsibility of taking the ships nearer than 400 yards.

† At Algiers, the Queen Charlotte, bearing Lord Exmouth's flag, was brought within 50 yards of the mole.

‡ Captain Fisher, R. N., basing his calculations on tonnage and omitting the 20-pounders, arrives at the conclusion that it is now necessary to be 620 times as good a shot with the Inflexible's guns as with those of a line-of-battle ship; or, in other words, that a miss is enhanced by this number as a multiplier.

whether a line-of-battle ship, engaged at 500 or 600 yards, had not actually a better chance of obtaining such a hit than an Inflexible at 2000 yards. Comparing gun with gun, the accuracy of fire has immensely increased. Comparing ship with ship, the chances of hitting have probably diminished, notwithstanding that naval gunnery has greatly improved in the last thirty years. The ranges at Alexandria were somewhat long—less than half those adopted by the French at Sfax, however—but it is not certain that ships will gain a balance of advantage in future by closing with good shore batteries properly manned. They will, it is true, be able to bring their machine guns into action; but the effect of the latter will be neutralized in the case of B. L. guns by the protection which can be provided, and by better protected machine and quick-firing guns on shore. If the shore batteries consist of well-designed and dispersed barbettes, with good cover for the detachments, the effect of the fire of the ship will in some respects actually diminish as she reduces her range. Shrapnel will become useless. The disadvantage of the ship will be the more pronounced as the elevation of site of the battery increases. Her one considerable advantage is that being nearer she has a better chance of picking out and inflicting a direct hit on the shore guns themselves. But a shore gun offers a very small front target, and if the guns support one another well the ship will not always be able to get a broadside shot at one barbette gun without laying herself open to the close unreturned fire of another. The comparative targets of the single ship and single gun are enormously against the former, and if there is sufficient dispersion it is clear that it is this comparison which must be instituted and not that of the ship and battery. Practically, however, the ship will in many cases have little option in the matter of range on account of submarine mines and the action of fast torpedo boats; while, in most cases, it is possible for the designer of the shore battery to fix the minimum range at which a vessel of given type can engage it. If the tactics adopted by the French at Sfax—boats at "a few hundred yards," gun-vessels at about 2300 yards, ironclads at 7000 to 4300 yards—were tried against well-armed and well-fought shore batteries, the policy of the latter would be evident. First dispose of the boats with machine-gun fire and case; then sink the gun-vessels with common shell, treating them simultaneously with shrapnel; finally, commence deliberate fire with armor-piercing projectiles and common shell on the ironclads. The three operations can be successively carried on with considerable security. It will need a great deal of shooting from the gun-vessels before a shore gun is grazed, and the ironclads will do no harm at all to the defenses. At Sfax, after a remarkably deliberate fire of 2002 projectiles delivered under peace-practice conditions, the "defensive power" of the place is reported to have been "practically uninjured."

Some facts drawn from the Alexandria action throw a strong light on the question of the accuracy of fire to be expected from ships. Meks Fort, a prehistoric work, armed with five heavy R. M. L. guns, nine S. B. guns and five mortars, was engaged by the Monarch, Penelope, Invincible and Téméraire for about three and a half hours. During one hour the Inflexible contributed a portion of her fire. The ranges of the three first-named ships varied from about 1200 to 1000 yards, that of the Téméraire was 3500, and of the Inflexible 3800 yards. The Invincible and Téméraire were anchored throughout the affair. The guns of Fort Meks were practically all *en barbette*, the three heaviest of them firing over a 4-feet 8-inch parapet, the interior wall of which projected 1 foot 10 inches above it, with a thickness of 2 feet 6 inches. During the action not a single gun was dismounted or disabled, and two only were touched by heavy projectiles, which just grazed them, leaving indents 1¼ inches deep. One gun was knocked over by an 8-inch Palliser shell from the Penelope, fired at short range after the work was silenced, when, therefore, there was no return fire and no smoke enveloping the battery. The two grazes may of course have been similarly obtained. Altogether about 580 heavy and 340 light projectiles were fired at Fort Meks. Theoretically, of course, this work should

have been silenced in ten minutes by the machine guns of the inshore squadron alone. That Fort Meks was able to reply for more than twice three hours to the overwhelming fire poured into it, clearly shows that low-level barbette batteries, if properly built, can well be fought. If this particular work had been constructed in accordance with the most elementary principles of defense; if the gunners had been able to handle the R. M. L. gun as well as they did the smooth-bores;* and if the armament had been supplemented by a few machine and quick-firing guns on the flanks and in Fort Namusia above, the ships would have been defeated without any difficulty.

Again, the Inflexible, at about 3500 yards, partly at anchor and partly under weigh, engaged two "most troublesome" 8-inch guns in Oom-Kabebé for about four and a half hours. She was simultaneously engaged with Fort Ras-el-Tin. The two Egyptian guns fired over 4-feet 3-inch sills in a straight parapet 5 feet 6 inches high, and were about 36 feet apart without any intervening traverse. The whole sea-front parapet of the work was hit nine times, the top of the counterscarp or glacis three times. The extreme hits were 120 yards apart. The face containing the two 8-inch guns was hit four times, three hits occurring on the superior slope and one on the cordon of the scarp. The three hits on the superior slope made large craters, the shells bursting well. One of them blew in the revetment wall between the guns for a length of 12 feet and a height of 3 feet. Neither gun was touched except by masonry splinters. If these guns had been 10-inch, manned by English gunners, and the Inflexible an unarmored cruiser, the latter would doubtless have been sunk or disabled, while the unarmored ends of the Inflexible herself would have suffered severely. The cost of mounting these guns, including the thickening of the old parapet, may have reached £100. In the whole action, in spite of the many advantages on the side of the ships, the total number of hits on the parapets of all the works—*i. e.* on the superior and exterior slopes—was about 1 in 19 rounds, excluding shrapnel and segment. Considering that a large proportion of these hits were on exterior slopes and were practically thrown away, while the average was certainly improved by some short-range practice after the works were silenced, the risk of a direct hit incurred by a barbette gun certainly does not appear to be excessive at moderately long ranges. In many respects the action at Alexandria supplies a wholesome corrective to views based mainly on too wide a generalization from unsuitable data. Thus, there can be little doubt that far too much accuracy has been expected from the fire of modern ships of war, and that the expectation has been derived from practice at Shoeburyness, and from the results obtained in experiments with siege guns. It would not have been impossible to carry out a series of experiments in which ships should fire at extemporized shore batteries under conditions as far as possible assimilated to those of service, the results being carefully noted; but such experiments were wanting, and exaggerated expectations were inevitable. Another generally accepted deduction from the Alexandria affair, and one extremely important to the defense, is that it is useless for ships to engage earth batteries by circling in front of them. It is necessary either to anchor or steam up to a buoy to fire, and the elliptic courses which theory delights to prescribe must be utterly given up where coast defenses cease to proffer a target.

Turning to the question of the employment of common shell against earthworks, Alexandria also affords subject for reflection. Probably the most destructive result which can be obtained by a common shell is a hit delivered with a descending angle a little short of the crest of a battery, blowing it in on the gun and detachment, thus practically adding a shrapnel effect to that of common shell. At Alexandria altogether 11 such hits were obtained out of 1620 rounds, 7-inch and upwards; but many of these did not occur in front, or nearly in front, of guns, and in a well-traversed battery would have been quite ineffective. With proper dispersion of guns—even without dispersion, if the

* The Invincible was hulled 15 times and the Penelope 8, in addition to receiving a round shot in one of her ports.

batteries are well traversed—the chances of such a hit are simply insignificant, even at moderate ranges. Where the guns have a good command such a hit can—as will be noticed hereafter—only be obtained at very long range. Moreover, the employment of iron glacis plates in front of barbette guns would give complete protection to the crest. Very effective results against men are obtained by a shell which, with a descending angle (the larger the better), just skims the crest and bursts on it or a few feet in rear. Are the risks of such a hit excessive? Large descending angles mean extreme ranges. If a time fuse is used, the accuracy required is measured in hundredths of a second. If a percussion fuse is used, it must be delicate and instantaneous, with a view of bursting on the crest, in which case it will be perfectly useless for purposes of weakening a parapet. If it does not graze the crest, it will, with all ordinary angles of descent, burst on the ground beyond, too far away to produce any serious loss. This, of course, presupposes that the emplacement is open to the rear, as it should be wherever possible. A common shell just clearing the crest of a circular pit* would catch the wall beyond and burst, probably killing every man of the gun detachment, and unquestionably so blocking the emplacement that it might take hours to clear the gun platform. In numerous existing cases guns are mounted close in front of walls admirably placed for increasing the dangerous target.

Again, to burst a common shell in the air in front of an earth battery with embrasures, or a barbette with a high parapet, is practically useless. This was fully recognized in Admiral Porter's orders before the attack on Fort Fisher: "All firing against earthworks when the shell bursts in the air is thrown away." . . . . "A shell now and then exploding over a gun *en barbette* may have a good effect, but there is nothing like lodging a shell before it explodes." It is doubtless an excellent thing to burst a shell directly over a gun, but it would be interesting to know how many a ship would have to fire before obtaining such a result. Some idea of the difficulty of obtaining much searching effect with common shell from ships' guns is conveyed by the fact that at 2400 yards the 8-inch howitzer, our best high-angle weapon, under perfectly favorable conditions, gave two effective hits in 20 rounds.

Tables of penetration into earth and sand have found their way into various text-books with no words of qualification. It is hardly too much to assert that they are totally misleading. Whatever may be the penetration attained in specially constructed butts, or arrived at by calculation open to objection, it is now sufficiently established that parapets of earth or sand with exterior slopes will not hold projectiles so as to enable them to penetrate properly. At Alexandria the penetrations, judged from a very large number of examples, were extremely slight. The shells turned up at once and either ricochetted high over the works or were stopped and lay on the superior slope, base to the front. A 16-inch shell from the Inflexible, fired at under 2000 yards range, was thus stopped after penetrating less than 20 feet of sand. As might be expected, this tendency to be immediately deflected is still more marked in the case of the new B. L. guns. At Eastbourne an 8-inch B. L. Palliser shell fired at 1193 yards gave a penetration of only 6 feet into a loam parapet with an exterior slope 1 in 2. At Lydd the effect of three 9.2-inch B. L. Palliser shells, fired at 1200 yards against a similar parapet, was almost *nil*.

It may probably be laid down, therefore, as an axiom that the fire of a ship is altogether unable to breach or seriously damage a properly constructed parapet; that exaggerated estimates of penetration must be modified, and that in works not liable to a land siege nothing is gained beyond a certain point by adding earth protection. The Eastbourne experiments further go to prove that shells bursting on a superior slope and causing craters which do not extend to the crest can effect no damage whatever in an emplacement.

The question of shrapnel is, perhaps, even more important, since shrapnel is to some minds a species of bugbear. The real effect of the 417 shrapnel

*At Inchkeith the back wall is actually heightened on the very centre line of the emplacement.

and segment fired at Alexandria is somewhat difficult to estimate. Only information from the Egyptian side could clear up the point. One gun and carriage received 49 shrapnel-bullet hits, all apparently inflicted by a single 11-inch shell from the Téméraire, the head and base of which were picked up in front. This gun fired through an embrasure the neck of which had been previously ruined by the fire of the Inflexible. Moreover, it is probable that the hit was delivered the day after the action. The remaining shrapnel hits on guns and carriages might be counted on the fingers, but it is of course possible that very oblique grazes might not have left a distinguishable mark. Some of the naval officers engaged at Alexandria were impressed by the good results of their shrapnel fire, but these results would be considerably enhanced by the defects of the Egyptian works. In estimating the Alexandria results, it is particularly necessary to separate those which the shortcomings of the works rendered inevitable. The fact that a ship could silence the fire of the saluting battery on the line wall at Gibraltar with shrapnel would not be a convincing argument of the efficiency of the latter against coast defenses generally. At Meks—a work almost *à fleur d'eau*—there was hardly a place where the head of an ordinarily tall man would be covered if he stood close to the parapet.

The Inchkeith experiments, carried out in August, 1884, throw a certain light on the performance of shrapnel at Alexandria. In all, 30 rounds were fired from the 10-inch R. M. L. guns at ranges varying from 850 to 3500 yards, the average being about 2330 yards. The conditions, so far as the ship was concerned, were ideal. The sea was calm; the ranges could be obtained with great nicety; the firing was by single rounds and excessively deliberate; undivided attention could be given to each round; there were no elements of disturbance; the Inchkeith gun presented an excellent target. On the first day, out of 15 rounds fired with battering charges, one ball found its way into the emplacement. On the next day full charges were used, and two good bursts were obtained in 15 rounds. Four dummies were hit; six balls struck the gun, six balls and three splinters the carriage and platform. In addition, one of the elevating wheels was broken, and the traversing gear placed at the rear of the platform was disabled by splinters. The gun could still have been worked.

The spread of shrapnel bullets from heavy R. M. L. guns has not been experimentally ascertained. For present purposes, therefore, it is assumed to follow the same law as that enunciated in the case of field guns by Lieutenant-Colonel Nicholson, R. A.* Taking the lateral velocity as constant and equal to 90 f. s.,† the semi-angle of spread calculated as $\tan^{-1}\frac{90}{v}$, where v is the velocity of the shell at the moment of burst, agrees in the case of the 64-pounder exactly with the result actually obtained at Dungeness. In the case of the 10-inch R. M. L., the spread similarly calculated varies from 3¼° at the muzzle to 5¼° at 4000 yards. With this gun, therefore, in estimating the searching effect of shrapnel, it will probably be sufficiently accurate to add five degrees to the angle of descent, unless the shell is burst so far short of the object that the increased curvature of the trajectories of the bullets becomes of practical importance. In the case of some new B. L. guns, the angle of opening of shrapnel has been experimentally determined, and found to be as follows:

Gun.	Range, Yds.	Semi-angle of Opening. ° ′
12-inch B. L. Mark I.....	2000	4 34
	3000	4 40
9.2-inch B. L. Mark III.....	1665	5 0
4-inch	1100	5 10
	2000	5 50
	3000	7 0

*"Shrapnel Fire." †Calculated by Captain T. S. Jackson, R. N.

The possible searching effect will of course vary much with the height of the shore gun. Thus, with the service 10-inch M. L., using the 70-pound charge, a ship must be at 1750 yards distance to obtain a horizontal trajectory at the crest of a battery 300 feet high, while to obtain an angle of descent of six degrees she must move to 3350 yards. If the crest of the battery is 100 feet high, the corresponding ranges are 1050 and 2950 yards. A common shell arriving at an emplacement with a horizontal trajectory, can do little injury to the revetment wall. Striking only a few feet short of the crest, it will be deflected up, unless the burst is instantaneous, in which case (as proved at Eastbourne) the splinters all clear the emplacement. Practically, therefore, to be really dangerous, the shell must burst *exactly at* the crest, which means hitting a target a few inches high, as well as securing an instantaneous burst. Supposing a 10-inch R. M. L. shrapnel to be burst in the most favorable position possible, the bullets, in the case of a crest 100 feet above the ship's guns, will at 1000 yards have a drop of less than 11 degrees, and at 16 feet from an 8-foot parapet would be still five feet above the ground level. A just appreciation of the above facts will render apparent the difficulties under which the ship labors in delivering a searching fire, and perhaps serves to explain why the French ships do not carry shrapnel for heavy guns. These difficulties will be materially increased by the introduction of guns giving higher velocities. For example, the height of the new emplacements for B. L. guns on Stone-Cutters' Island, Hong-Kong, is about 210 feet. At this level, projectiles from the French 27 cm. gun with a muzzle velocity of 1664 f. s. will have a horizontal trajectory at 1750 yards, and a fall of 6°, or 1 in 9.7 only at 4000 yards. In the case of a higher-powered gun, such as our 9.2-inch, Mark III., with a muzzle velocity of 2065 f. s., the corresponding ranges would be about 2100 and 4800 yards. The searching power of the fire of modern ships is, therefore, strictly limited, and the difficulty of killing men behind a high parapet by shrapnel fire from high-velocity guns has, perhaps, been insufficiently appreciated; while the danger to the revetment in front of a barbette gun, or to the crest of a pit, cannot be regarded as serious.* As regards searching effect, ships are now in a worse position than they were 50 years ago, and when re-armed with new guns their power will in this respect be still further diminished.

It has been suggested that, in view of the difficulty above pointed out, a complete or partial return to short guns and low velocities is to be expected. It appears doubtful, however, whether our possible enemies, having arrived, after great efforts and vast expenditure, at remarkably straight-shooting long-range guns, will abandon them for relatively inaccurate weapons. This has certainly not been the practice in the past, and the resuscitation of smooth-bores—also at one time prophesied—is about an equally probable contingency. Again, though the value of curved fire of heavy shell from the coast battery against the ship is only now receiving general recognition, the use of howitzer fire from the ship supplies a ready argument against open batteries and disappearing guns. For several reasons, the result of the practice carried out from H. M. S. Hercules off Shoeburyness in August last was inconclusive. The fact nevertheless remains that, though the ship was anchored in smooth water, such an excellent high-angle gun as the 8-inch 70-cwt. howitzer was unable to plant a shell within 20 yards of a conspicuous target flag at only 1500 yards, and that two rounds fired with the same elevation and charge, on the same day, gave a difference in range of 370 yards. The admirable practice obtained at Lydd with this howitzer at 2400 yards is due to back-laying and careful observation. Howitzer vessels will have to engage at ranges not less than 4500 yards, or be quickly put out of action. It has yet to be shown how back-laying is to be carried out on board ship, how under ordinary conditions the clinometer

*General Sir L. Simmons stated in 1870, "What is the chance of a shot fired from an unstable platform, like the deck of a ship, striking a battery at 1600 or 1800 yards, so near the crest as to do any injury to it? I believe myself it would be absolutely throwing away ammunition to attempt it." (*R. E. Corps Papers, Vol. XVIII.*) High-velocity guns do not appear to have increased the chances of such a hit.

is to be employed unless the ship is aground, and how at long ranges observation from the tops is likely to succeed. The target offered by a disappearing gun will be an invisible horizontal circle some ten yards in diameter. The chances of hitting it may be imagined.

Some stress has been laid on the results which a modern ironclad might obtain from her auxiliary armament. Thus the Dupérré carries 14 5½-inch guns of new type and 12 Hotchkiss machine guns, in addition to her heavy armament. This auxiliary armament adds considerably to her total rate of fire, which, however, will still be inferior to that of a small frigate of old type. To use these guns, however, the Dupérré must fight broadside on, and as they have no armor protection, they would be in the same position, as far as protection is concerned, as the guns of a wooden frigate opposed to modern heavy-shell fire. If the shore guns were even moderately well handled, and especially if they were supplemented by a proportion of quick-firing guns, it might fairly be expected that this auxiliary armament would be very soon put out of action with a heavy loss in men; and it might be by far the best policy for such a ship to fight end on, using only her barbettes, and—except in the case of a battery on a high site—minimizing her target.

As regards the possibility of injuring the carriages of guns in shore batteries, the experiences of Alexandria were probably unexpected. Out of 35 R. M. L. guns under fire, there were, in addition to the dismounted guns, only two cases of injury of a damaging nature to carriages—a compressor arc broken and a front truck cut away by shell splinters. The case of a small, unfinished two-gun battery in Ras-el-Tin lines heavily shelled by the Inflexible and Téméraire is somewhat remarkable. The embrasures in front were almost destroyed and the guns bared, yet both carriages were perfectly serviceable and were subsequently mounted at Ramleh. The Alexandria affair seems to indicate clearly that, to disable a gun, a direct hit is necessary. It is worthy of note that two 9-inch Palliser shell, which actually burst in the turret of the Huascar, did not suffice to render either of the two carriages unserviceable.

As to the probable effect of machine-gun fire, the data, if not altogether complete, are extremely suggestive. Machine guns may be divided into two classes—1st, a continuously-fed gun, such as the multiple-barrel Gatling, Hotchkiss, Nordenfelt, and Gardner; 2d, a hand-loaded "quick-firing" gun. The former class is capable of delivering a very rapid fire of bullets or small shells; the latter fires shells up to about 6 pounds weight,* at the maximum rate of 10 or 12 per minute. At Alexandria the fleet carried about 70 1-inch 4-barrel Nordenfelts, and expended more than 16,000 bullets. The expenditure of Gatling ammunition was only 7000 rounds, and of Martini bullets 10,000. As to the results obtained, opinions have differed. It is submitted, however, that the number of hits on the guns and carriages of the defense may fairly be taken to afford some indication of those results. The hit of a Nordenfelt bullet on iron is generally unmistakable, but it is evidently possible that grazes at a very acute angle might have escaped observation. The total number of hits on guns and carriages was seven, and even this moderate number requires qualification. One hit was on the liberal target offered by the bracket of the Moncrieff carriage. This carriage stood upon the shore, the formality of building up protection round it having been omitted. The gun was of course not in action, and the natural fondness of the bluejacket for a good upstanding target can alone account for its being fired at.† The high exposed scarps of Forts Ras-el-Tin, Adda and Pharos distinctly showed every Nordenfelt hit, but the total number of such hits was quite insignificant. It is stated that at the Ingogo affair, where the artillery suffered severely from rifle fire, the guns were actually whitened by bullet splashes. A fair inference seems to be that

* A 40-pounder quick-firing gun, constructed at Elswick, has been tried with complete success, and gave *seven* aimed rounds per minute. A 12-pounder gun is now under construction.

† At least four heavy projectiles were also fired broadside on at this carriage, which received one splinter hit only.

the vast majority of the 16,000 bullets fell short, or, as was actually the case at Meks, flew well over the battery. Captain Fisher, R. N., states—"Most of our ships used their Nordenfelt machine guns, but nothing is known as to the effect produced. The bullets were found far and near, so it is to be feared the fire was not very accurate. It is difficult, indeed almost impossible, to see where the comparatively small Nordenfelt bullet hits." The conditions at Alexandria were not unfavorable to machine guns. The ranges of the inshore squadron were moderate, and the tops of the ships were above the level of the shore guns. Captain Lewis, R. E., in his lectures on "Permanent Fortification,"* remarks—"It might be quite possible for a boat armed with a machine gun to keep a heavy gun silent—that is, if the boat could manage to begin." It is not easy, however, to see why a boat firing at the water level should succeed, while the machine guns in the tops of the Penelope and Invincible failed for three and a half hours; and this opinion can only be regarded as the outcome of pure theory uncorrected by actual experience. The explanation of the apparent failure at Alexandria is, doubtless, that the ranges were, on the whole, too great for accurate practice under service conditions, and that, even at the less ranges, the smoke of the guns of the attack and defense, together with the sand thrown up and smoke caused by the shells bursting, utterly obscured the effect of the Nordenfelt guns, so that the men who served them had no idea where their bullets were going. Diagram III. shows the influence of high sites in modifying the searching power of the 1-inch Nordenfelt gun. A fall of 2° (1 in 28) at a crest 100 feet high can only be obtained at 1040 yards. In the case of the Hong-Kong emplacements above referred to, this angle of descent is unattainable at a less range than 1260 yards.

The experiments carried out at Inchkeith, where H. M. S. Sultan, under the conditions stated on p. 175, concentrated her fire on a single remarkably conspicuous shore gun, form an interesting comparison with the Alexandria results. The total number of machine-gun rounds fired was 15,210, by which fifteen dummies were hit. In the first four series 1541 rounds were fired, with the result of hitting one dummy. In the other series four Gardners and two Gatlings on deck fired 2815 rounds, obtaining three hits on dummies. In another thirteen machine guns fired 3874 rounds, hitting two dummies. This was target practice and the dummies remained fixed in the most exposed positions which the loading numbers could occupy.† Making the most moderate correction for the complete difference of conditions under which an action would have to be fought, it does not appear that even a barbette gun has much to fear from machine-gun fire, and the Alexandria results seem to be explained. The most that a ship could hope to do, by directing her whole machine-gun fire on a single shore gun, would be to keep it silent for a short period at an extravagant expenditure of ammunition. A few machine guns on shore would effectually prevent even this moderate achievement.

As to the performance of the 6-pounder quick-firing gun also, the Inchkeith experiment affords some teaching. In forty-eight rounds, at ranges from 1500 to 1900 yards, one dummy was hit. On the other hand, in five subsequent rounds the target gun—turned broadside on—was hit three times; but since, in this case, thirteen machine guns were simultaneously in action, the effect on the dummies cannot be stated. This excellent result shows the kind of target practice of which the 6-pounder is capable; but it may fairly be questioned whether its introduction has not conferred superior advantages on the defense. Against the unarmored portions of a ship it will prove extremely effective, and to keep the crew behind their armor and the officers shut up in conning-towers will be a considerable gain. In any case the quick-firing gun itself will

*R. E. Occasional Papers, Vol. VII., 1882.

†Nos. 2 and 3 stood always *on* the loading stage, about half their bodies being fully exposed. No. 5, who was supposed to serve the muzzle derrick—a duty he could have performed with a boat-hook from the loading-way in perfect security—stood actually on the platform girder, and was exposed down to his knees.

probably not be carried behind armor, and the unarmored portions of a ship may be expected to suffer very severely in the first action in which modern coast-guns are properly handled.

The introduction of heavy breech-loaders for land service affects the question of protection in the following ways: The length and comparative weakness of the chase are somewhat unfavorable. Even with the otherwise complete protection promised by a casemate, cupola, or turret, the great protrusion of the gun will render it liable to a hit which might easily disable it. At Eastbourne the shell of a 6-pounder Hotchkiss quick-firing gun, striking the chase of a 10.4-inch B. L. gun, penetrated into the bore. At Shoeburyness a steel shell from the same quick-firing gun, striking the chase of a 9.2-inch B. L. gun at 150 yards, raised a bulge 0.4 inch high in the interior. The precise effect of such an injury cannot be stated. A portion of the chase of the damaged gun would obviously be blown off by the next round fired, and more serious consequences are evidently possible. The effect of a projectile from the quick-firing gun striking the face of the muzzle of a heavy gun has not been ascertained. Again a single shell from a 6-inch B. L. cut off two feet four inches of the chase of the 10.4-inch B. L. gun, and even the 5-inch B. L. is capable of inflicting serious injury at comparatively long range. To chase injuries, guns *en barbette* are not more liable than those in turrets; while long guns in casemates may evidently be seriously damaged by medium B. L. guns outside their arc of possible reply. In one sense, therefore, the introduction of long guns has reduced the value of front armor, since there is a partial anomaly involved in providing a mass of iron which, after all, leaves the weakest portion of the gun it affects to shield exposed to injury from light projectiles. It is to be remembered, further, that the considerable amount of smoke issuing when the breech is opened constitutes an argument of some importance against mounting the new guns in casemates or roofed turrets. A breech-loader, however long, can be loaded *en barbette* while offering a minimum target to front fire of all kinds, and if the operation is performed at elevation the actual loading numbers are admirably protected by the breech of the gun itself. Unless, therefore, the fire of more than one ship can be concentrated upon individual guns, which, with dispersion, careful sighting and a moderate angle of training, will not be easy to effect, the loading numbers of new B. L. guns *en barbette* will be well protected in spite of their greater distance from the parapet; while the great disadvantage attached to side loading in the case of M. L. guns—the presentation during considerable periods of a broadside target—will be obviated. On the other hand, the breech mechanism brings a new source of danger. A mere burring up of the breech-screw by a machine-gun bullet, or the cutting away of the locking lever by a shell splinter, might suffice to silence the gun for a long time. These risks can, however, be easily met by a steel hood enveloping the breech, or by special steel protection to individual points of weakness.

Von Scheliha, in his treatise on "Coast Defense," says: "Guns mounted *en barbette* may always be disabled by an ironclad." The remark might with advantage have been made more general. All guns, however mounted, *may* be disabled by an ironclad, and the question is merely one of comparative risk. The Grüson plates of the great Spezzia cupola, four feet two inches thick, and each weighing very nearly 91 tons, will provide no protection whatever for the long, weak chases of the two 16-inch guns, which could be disabled by the projectile of a 5-inch B. L. gun carried on board ship. Under these circumstances, it is not surprising that the barbette principle still finds favor, and that it is not proposed to give front-armor protection to any of the guns mounted in the new coaling-station defenses. A barbette gun cannot well be disabled except by a direct hit, and the vulnerable target presented to front fire is little larger than the breech section. It has been asserted that the new B. L. guns cannot be held in a barbette mounting, and that turrets, cupolas, or casemates fitted with cumbrous "yokes," are, therefore, necessary. The 9.2-inch B. L.

gun has been held at Lydd by an extemporized anchorage in shingle, and has also been successfully mounted on board ship. The 10-inch B. L. has for some time been mounted *en barbette* at Cadiz and successfully fired. The 43-ton 12-inch has also been tried on a barbette mounting. This objection may, therefore, perhaps be abandoned.

The drawbacks to this mode of mounting are two—exposed flanks, and the absence of overhead cover to the detachment. The maximum angle at which the gun can subtend at the ship—in other words, the area of the target—can be limited to any extent desired; while the practical carrying out of systematic cross-firing from ships will not be quite so easy as it appears on paper. The ship may be expected to show a natural tendency to concentrate her fire on the guns which are hitting her; and if the Inflexible, at Alexandria, had been hulled every other minute from Oom Kabêbé, she would not, in all probability, have divided her fire so impartially between this work and Fort Ras-el-Tin.

Of all methods of mounting yet proposed, the disappearing principle offers the greatest advantages, and, provided that the mechanical difficulties can be overcome, this method will receive a wide adoption. The gun, laid under cover by a position-finder, will be vulnerable only for a few seconds before each round. Its exact position can only be identified during the brief period of visibility. There appears to be no satisfactory mode of attacking it.

The experiments carried out at Portland Bill in November, 1885, give some idea of the difficulty a ship will experience in dealing with a gun of this class. The dummy—a wood and canvas model of a 10-inch B. L. gun—appeared and disappeared on the natural surface of the bluff, working up and down through an opening in a wooden shield at the ground level. The period of visibility laid down by the conditions of the trial was half a minute in every three minutes, and a small charge of powder was fired electrically at the moment of disappearance to represent the discharge of the gun. H. M. S. Hercules, at ranges varying from 750 to 950 yards, fired 6910 rounds in ten minutes from 1-inch and rifle-calibre machine guns, and 29 rounds from the 6-pr. Hotchkiss quick-firing gun. The whip used for hauling down the dummy unfortunately broke at the end of the 7th minute. For the three following minutes, therefore, the dummy was exposed and, as the ship continued her fire after the bearing laid down had been passed, it presented a broadside target. Notwithstanding that the dummy was exposed more than twice as long as it was intended to be, and about four times as long as a real gun need have been, it received only 16 direct and 9 splinter hits. The horizontal wooden shield showed four scratches, and one Nordenfelt bullet dropped into the gun pit. It would, of course, be perfectly useless to employ machine-gun fire at a disappearing gun; but the above result supplies an interesting comparison with that obtained by a similar armament at Inchkeith. To halve the number of hits obtained at Portland, so as to correct for the unfortunate accident to the whip, is more than fair, since the greater portion of these hits were undoubtedly obtained when the gun had ceased to be disappearing and presented a broadside. Accepting this correction, the comparison of hits on the guns at Inchkeith and Portland is about 12 to 1, although the average ranges in the two cases were as 1000 to 825 yards respectively. In addition, 15 rounds of 10-inch common shell and 13 rounds of 10-inch shrapnel were fired at the Portland dummy at ranges from 2200 to 2845 yards without any result whatever. In the common-shell series, the error in range varied from 300 yards short to 300 yards over, and the horizontal dispersion 120 yards left to 150 yards right, showing clearly the difficulties of practice against such a target.

The above experiment, although by no means satisfactory from either the point of view of the attack or defense, serves nevertheless to substantiate the advantages claimed for the disappearing system. These advantages can obviously be reduced to a minimum, however, by applying the system as at Newhaven, Popton, Hubberstone, and Corradino Lines, Malta.

The general conclusions which it has been sought to arrive at may be stated as follows:

1. The all-round protection conferred by the turret will be sure to recommend it, but expense, combined with other considerations, will limit its adoption to low, cramped, advanced or island sites. The great range of modern guns will somewhat check the tendency to push forward the shore gun to the water's edge, where a high site suitable for a barbette is available within a few hundred yards to the rear. In any case, the provision of a turret can be justified only where a disappearing mounting is proved to be impracticable. Limitations of range due to considerations of the size of the port of a turret will not be tolerated. The heaviest guns will therefore be port-pivoting, and will be worked by hydraulic power, proved to be perfectly successful on board ship. At distant foreign stations, where there are no facilities for repairs, the turret can, under no circumstances, be adopted. In very hot climates it may prove inadmissible. Where there are moderately high sites of sufficient area it is altogether unnecessary. The relative inaccuracy of the fire of ships renders it probable that a turret would not be frequently hit in action, and the fact that, as proved at Buchau, a single segment of a Grüson turret broke up under four closely adjacent hits from a 12-inch gun, does not condemn chilled-iron armor. Such a favorable result would never be attained by ships in action. The question between wrought-iron, steel, and cast-iron armor is, therefore, mainly one of economy. A sand or earth parapet up to the level of the glacis plate will be provided, where practicable, as at Kronstadt. In other cases, a gentle slope of hard concrete will be substituted.

2. The cupola, understanding by the term a conical turret containing a single gun worked by hand, is subject to some of the above limitations. The Eastbourne experiments showed that a cupola, the strongest plate (7-inch compound) of which was shattered by three 8-inch B. L. shrapnel striking blind, approached the limit of hand-working. The adoption of a floating pivot would doubtless facilitate rotation to a great extent; but it seems probable that a cupola to justify its existence must carry a weight of armor necessitating the employment of power, and thus become subject to the same limitations as the turret, of which it is a mere modification. An inadequately armored cupola appears to be quite as dangerous as a barbette mounting, while it is far more expensive.

3. The continuous iron front or the Grüson battery may still be employed under certain circumstances—for example, on a cramped, low site where great volume of fire is required over a limited arc, or where an all-round fire is needed of limited intensity on a given arc, but such that the flank and rear guns shall be available after those in front have been silenced. In such a case, "position-finding" would be a necessity, since the smoke produced by the large charges now employed renders the direct laying of casemate guns entirely dependent on chance conditions of wind and weather. Armor may also conceivably be desirable to protect machine or quick-firing guns in connection with turrets. This form of protection will usually labor under the disadvantage of offering a large target and involving heavy expense, while it will sometimes entail crowding of guns where dispersion is possible. As in the case of the turret, range cannot be sacrificed to size of port, and port-pivoting, probably necessitating hydraulic power for the larger nature of guns, must be adopted.* The thickness of metal in an armored front should be well able to withstand the heaviest projectiles that the attack is likely to bring to bear upon it, and the possibility of subsequent strengthening should not be lost sight of. Since cast-iron armor cannot well be subsequently strengthened, a Grüson battery should possess a resistance decidedly greater than that now required.

4. The disappearing principle will undoubtedly attain great development. No other mode of protection confers equal invisibility. A disappearing gun in a

* Port-pivoting has already been partially attained by the "small-port" carriages adopted for 10-inch and 12.5-inch M. L. guns, but entails the great disadvantage that the field of view is extremely limited. Guns thus mounted would, therefore, be best laid by the aid of a depression position-finder.

well-placed pit provided with a horizontal splinter-proof shield is far better protected than in an impenetrable turret. Moreover, a gun so mounted possesses the great advantage that future advances in the offensive power of ironclads are little likely to diminish the value of its protection. For the new breechloaders the counterweight carriage is unsuitable, and hydro-pneumatic mountings have not yet by any means reached their full development. It has been shown that these mountings can be satisfactorily applied to the 8-inch B.-L. gun,* and experiments shortly to be tried will test their application to the 9.2-inch and 10-inch B. L. Experts hold that the principle can be extended without any great difficulty to the 68-ton B. L. gun. Were several adjacent guns to be thus mounted, it may prove desirable to provide a small steam engine, able, by pumping, to ensure the maintenance of the pressure necessary to raise the guns. The engine would be merely a reserve of power intended to save manual labor, and to meet the case of leaky glands or defective cup leathers. For the old muzzle-loaders there is no reason that a counterweight system, such as that of Colonel Moncrieff or Major King, should not be employed for guns up to the 10-inch R. M. L. The system need be applied only in cases where low sites, with deep water within short range, are unavoidable. The Moncrieff mounting is necessarily costly, but the gun is far better protected than if mounted in a casemate with a heavily armored front, while in the opinion of the special committee appointed to consider the question of counterweight carriages, one disappearing gun may be estimated as equal to two in casemates. A simpler system may possibly be devised, and rate of fire might perhaps be sacrificed in consideration of the great protective advantages. The value of the disappearing principle greatly depends on the way in which it is applied to the actual site. With adequate care the position of a gun so mounted may in most cases be rendered absolutely indistinguishable except during the few seconds of exposure before firing. If, however, this fact is not fully recognized, the system loses one of its special advantages.

5. The principle of the Collingwood mounting appears to be eminently applicable to coast-defense guns of the heaviest class. The measure of protection provided is practically equal to that of a turret. It is true that this protection is far inferior to that conferred by the disappearing principle, but the practicable difficulties in the case of the heavier guns are possibly less. The target offered to the ship is so small that the comparatively slight risk of a direct hit—almost the sole danger to which a gun thus mounted is liable—may perhaps be accepted without hesitation. The loading numbers have complete security. With the heavier guns hydraulic power must undoubtedly be employed, and there appears to be no better mode of applying it. Whether the hydro-pneumatic principle can be applied to this mounting, so as to realize a storage of recoil, and enable several guns to be worked by a small engine, remains to be seen. The addition of an armored glacis will be desirable in the case of low sites, and it is possible that chilled iron may be suitable for the purpose.

6. The barbette, with a central pivot, is likely to be the most general form of mounting. The heaviest of the new guns at present tried with this mounting is a 43-ton B. L gun, firing a charge of 400 pounds. Whether heavier guns, up to the extreme limit of hand-working, can be thus treated, remains to be seen. With the larger natures a front pivot may be necessary, and hydraulic power must be employed. The main danger of the barbette mounting is on the flanks, and protection should rarely be sacrificed to a wide angle of fire, where it is possible for an unengaged ship to take up a flank position. An angle not exceeding 120 degrees, with bonnettes, will be the most generally suitable; but to lay down an arbitrary limit is evidently undesirable, and each case must be dealt with on its merits. Circular pits are objectionable, but much less disad-

*The fact that this mounting—on its first trial—stood 46 rounds, including 5 rounds with 210-pound proof cylinders, with charges varying from 105 to 112 pounds Prism[1] (black), without a breakdown, is most encouraging.

vantageous on high sites. The emplacement should have the minimum possible of exposed masonry above the line of descent of heavy projectiles fired at a range of 3000 yards. It may prove desirable to protect with iron the crest over which the gun fires, especially where considerable depression is required. The Eastbourne experiments show that a skin of iron plate supporting good concrete would be a suitable form of crest, but it is possible that the place of concrete may advantageously be taken by sand alone. The range must not be diminished by limiting the possible elevation. Since the carriage designed at Elswick for the 43-ton gun admits of 20°, this limitation would not appear to be necessary. The protection of exposed gear on the side of the carriage and of the breech screw (when withdrawn) from the chance hit of a shell splinter, as well as the whole question of steel hoods to cover the loading numbers, merits careful attention. Under some circumstances the front pivot and embrasure will be advantageous. It is now certain that the results of experiments with siege guns need not be held to condemn the embrasure for coast batteries. Should the difficulty of under-cover loading for the existing M. L. guns prove incapable of satisfactory solution,* it may be worth while to accept the limited angle of training and adopt the embrasure for these guns, mounting a larger number of guns to cover the same field of fire, in order to gain the considerable protection against shrapnel and machine guns which the embrasure affords to the loading numbers. Bonnettes with vertical stone cheeks 8 feet high, as at Fort Leonardo, Malta, and elsewhere, will scarcely be repeated, and earth or sand will be universally employed. Guns *en barbette*, except in cases where a sky background cannot be avoided, may be rendered almost invisible at moderate ranges. Even the 100-ton guns at Malta are extremely difficult to make out at 2000 yards; those at Gibraltar could easily be rendered at least equally inconspicuous.

7. In sighting guns, dispersion will be aimed at as much as possible, and the placing of the most powerful guns of a battery in closely adjacent emplacements will always be avoided. High sites will be preferred for open batteries. Against the more heavily armored modern ships, the attack on the deck may possibly prove by far the most effective course. Barbette ships seem specially ill-qualified to resist such an attack. The very accurate fire of the new guns will be favorable to it. It is true that the flatter trajectories will produce a relatively greater tendency to rebound from the deck plating, but, on the other hand, there are plenty of objects on the deck of a ship capable of turning down a projectile, and once turned down it would be rash to attempt to predict its further course. The importance of high sites and dispersion was clearly pointed out by Sir Harry Jones forty years ago:—"It becomes the duty of the engineer charged with the defenses of a maritime fortress so to arrange his batteries that the defenses may be from several points distant from each other . . . . on commanding situations and not *à fleur d'eau*, which has heretofore generally been the case. As auxiliaries, batteries so placed on many occasions will be found very useful, but for the principal defense height must be attained."† Todleben drew the same moral from the remarkable effect produced by the fire of the telegraph battery at Sebastopol, and naval men have never hesitated to own their dread of plunging fire. There is no ship afloat which could not be put out of action by such guns as the 6-inch and 8-inch B. L. mounted on high sites, and it may be desirable in some cases to sacrifice even a thousand yards of range to gain the double advantage of plunging fire, and relative immunity from risk.

8. Invisibility will be striven for by all possible means. It is the cheapest form of protection. Guns will be suitably colored. Clean-cut lines and even slopes will altogether disappear, while vegetation will be judiciously encour-

*The chain-rammer experiments carried out with a 9-inch R. M. L. gun at Eastbourne in July, 1885, cannot be regarded as altogether satisfactory. The average time per round was 3 minutes 19 seconds, and the difficulties of ramming increased after a few rounds.

†Editor's note—"Peninsular Sieges."

aged. The background and foreground of gun emplacements will be made the subjects of careful study. At Alexandria the great difficulty of our ships was to find a definite object to aim at. In a well-designed earth battery there should rarely be anything clearly defined. The very few natural advantages of the Alexandria sites can be improved upon in most cases, provided that the necessary amount of care and thought is forthcoming.

9. Parapets 35 feet thick, with flat exterior slopes, will be ample for all purposes of protection, and are likely to be equally serviceable years hence. Sand will be employed in front of gun emplacements wherever possible. A mere layer two or three feet thick on the top of an earth parapet has been found to be advantageous.

10. Since it is now certain that ships will have to anchor, or come back to a given point to fire, when seriously engaging earth batteries, the employment of curved fire against them will in time obtain wide adoption. The fact that, with an 11-inch howitzer at 7300 yards, five shots out of ten were placed on a target representing the deck of the Inflexible,* is sufficiently significant. Later experiments in Russia and Italy fully bear out this excellent result, while the depression position-finder opens out new possibilities. Already the Italians are mounting howitzers in large numbers for coast defense—at Venice the numbers of howitzers and guns are 45 and 22 respectively, three forts being armed with howitzers only. The U. S. Board on Fortifications propose 144 12-inch rifled mortars for the defenses of New York alone. The heaviest ironclads are exposed to deck attack by means of curved fire, and the moral effect of this fire, delivered from small groups of heavy howitzers, will suffice to prevent them from anchoring or even manœuvring at slow speed within range. The service 9-inch R. M. L. gun, re-tubed and polygrooved, has given excellent results used as a howitzer. The larger natures of short R. M. L. guns will before long be similarly utilized, and will be much improved in range and accuracy. The proper employment of large howitzers is to group them in fours behind natural folds of ground, or banks rendered indistinguishable from their surroundings, employing salvo-fire directed by a position-finder. The re-tubed guns will, in many cases, be adapted also for direct fire ; but when thus used their value as howitzers is impaired by their necessarily increased visibility. It is, therefore, desirable to regard the two modes of employment of these guns as completely distinct, and while mounting them in some cases so as to retain the power of direct fire at moderate ranges, to provide concealed howitzer batteries in addition.

11. The defense will employ machine and quick-firing guns in dispersed emplacements, well separated from those of the heavy guns. This auxiliary armament can be rendered practically invisible at moderate ranges, and should find no difficulty in keeping down the fire of corresponding guns on board ship, as well as thoroughly searching the unarmored portions.

12. The advantages in respect to range-finding, and the direction and concentration of fire which the shore battery possesses over the ship, deserve to be utilized to the utmost possible extent. The position-finding system devised by Major Watkin, R. A., has attained perfection. Its practical value has been amply attested by experiment, and its general application cannot be much longer postponed.†

In conclusion, it is maintained that, having regard to future possibilities, the defense must proceed rather in the direction of scientifically increasing the many tactical and other difficulties of the attack than in merely piling on front armor. It may be doubted whether thickness of iron or steel will ever exercise a determining influence on an action between ships and coast defenses. The Amiral Baudins and Lepantos can be defeated without ever penetrating their thickest plates. The want of practical experiments in naval gunnery has

*Journal R. U. S. Institution, 27th January, 1882.

†The Russians have had a system of position-finding in practical operation at Kronstadt and Sebastopol for some years.

naturally resulted in anticipations as to the effect of the fire of ships which can never be fulfilled. Without waiting for Alexandria, it could probably have been established that vessels in motion are quite unable to silence guns in dispersed emplacements even at low levels, and this fact alone would have been worth ascertaining. There are many more points on which light might have been thrown by such experiments as those at Inchkeith and Portland. The back of the Rock of Gibraltar, the island of Filfilla, off Malta, offer convenient sites; while a suitable island could probably be found on the west coast of Scotland. The expense would surely be justified, since, after all, the chances of being hit materially affect the settlement of most questions of coast defense. If such questions are to be ruled mainly by mere considerations of armor penetration, and the battle between coast defenses and ships is regarded—as has sometimes been the case—in the light of a mere contest between the gun and the plate, how are we to forecast the future?

Lecturing in 1873,* Lieut. (now Major) English, R. E., one of the most able exponents of the iron method, stated:—"The development of curved fire, which would appear to be the most likely method of attack, would surely not be such a difficult task as the development of armor-piercing projectiles. It is almost certain that no material improvements will be made in the shape and material of the latter; and it appears probable that the limits of weight and velocity are already nearly reached, on account of the difficulty of finding any material to withstand the strains produced in the inner tubes of heavy guns by the enormous charges even now found requisite. We may, therefore, venture to hope that comparatively little, if any, further expenditure will be necessary to maintain the present invulnerability of our iron coast defenses."

Curved fire from ships cannot be said as yet to have received any "development," unless, indeed, the proposed construction of a cruiser carrying four Zalinski air-guns for the United States Navy can be regarded in this light. Meanwhile, the improvement in armor-piercing projectiles has been extraordinary, as was brought home to most minds by the recent performances of the Firminy shell. The 12-inch 35-ton gun of 1873 has a muzzle velocity of 1390 f. s.; the 9.2-inch B. L. wire gun of to-day has 2500 f. s. The maximum internal strains are being reduced.† The projectile of the 35-ton gun weighs 714 pounds; that of the 100-ton guns, now several years afloat—the Duilio was launched in 1876—weighs about 2000 pounds. The 10-inch R. M. L. of 1873 burns 70 pounds of powder; the 10-inch B. L. of 1886 at least 250 pounds. The inadequacy of most of our "iron coast defenses" is a matter of common notoriety, and large sums would be needed to restore an "invulnerability" which was even rendered doubtful by the introduction of the 38-ton gun in 1874.

REPORT OF TORPEDO ATTACK AND DEFENSES OF U. S. S. TENNESSEE.

NORTH ATLANTIC STATION,
U. S. FLAGSHIP TENNESSEE (FIRST RATE).
NEWPORT, R. I., *September* 21, 1886.

Rear-Admiral S. B. LUCE, U. S. N.,
Commanding U. S. Naval Force on North Atlantic Station.

Sir:—In compliance with your order of the 17th inst., directing me to furnish a description of the torpedo attack and of the defenses of this ship on the night of the 16th inst., etc., I have the honor to submit the following regarding the attack, and append a copy of the rules by which the torpedo boats

* R. U. S. Institution, 31st March, 1873.

† Thus, in the 100-ton R. M. L. gun, 469 pounds P^2 gave a pressure of 20.8 tons; while 551 pounds Fossano powder produced only 17.37.

were to be governed. These rules were made by Commander Goodrich, U. S. N., umpire, and two officers of the Torpedo Station who were to be of the staff of judges—with myself as commander of the defense.

In anticipation of the attack, the ship was defended as follows and as more fully shown by the accompanying drawing:

The defenses forward consisted of the fore and main topsail yards lashed together at the outer end and spurred out by the flying jib-boom from the cutwater, the after ends being spread out by the fore and main topgallant masts from each bow. The forward torpedo spars were lowered and guyed well forward and the intervening spaces filled out with the fore and main trysail gaffs, one on each side. There was a guy from the jib-boom to the end of the flying jib-boom to secure the latter in position and as an additional security to the heel-lashing. The flying jib-boom was guyed from the forward end to the ship's side. The defense astern was composed of the cross-jack yard on the starboard side and several smaller spars and pieces of timber lashed together into one compact mass on the port side. The after ends were lashed together and spurred out by the mizzen topgallant mast directly astern. The forward ends were spread out and lashed to the fore and main topgallant yards as outriggers from each quarter. The after torpedo spars and lower booms were rigged out and drooped into the water. The mizzen topsail yard was used amidships on one side and the spanker gaff on the other side as spurs. Additional spurs were made by lashing capstan bars to the ends of the boat strongbacks, making them thirty-five (35) feet long, and placed along the ship's side at intervals of about forty (40) feet, the heels being lashed at the water's edge to the steel ridge-rope, which was passed around the ship and set up forward, and which is shown in red ink in the accompanying sketch.

An eight (8)-inch hawser was middled, the bight secured to the outer ends of the after booms and the ends carried forward on each side and set up taut to the outboard ends of the fore and main topsail yards and strongly lashed to the outer ends of the spurs at the uniform distance of thirty-five (35) feet from the side. A seven (7)-inch hawser, similarly secured, was lashed on six (6) feet inside of the first, capstan bars were then lashed to the two hawsers, athwartships, at regular intervals between the spurs, the ends protruding outboard two or three feet, the idea being that the thrust by the torpedo boats should be taken up by the two hawsers, instead of by the one, and the protruding ends of the capstan bars to disable the launches. On the port quarter a netting was secured as a propeller-catcher and rope ends were allowed to trail from the spur ends for the same purpose. The outer hawser, by means of tricing lines and topping lifts on the spurs, was triced up from the water about six inches, in order to prevent its being submerged by the boats upon striking. Eight improvised torpedoes were distributed along the defenses, to be fired at will from the firing-board on the after bridge. In addition, the Hotchkiss revolving cannon, Gatling gun and the two howitzers were fully manned, and assisted in the defense, together with the marines as sharpshooters. Four streams of water (two from the steam and two from the hand pumps) were also made use of to represent the firing of machine guns.

As soon as darkness had fully set in, four picket boats were sent out to a reasonable distance, one four points on each bow and one four points on each quarter, each with orders to patrol over an arc of four points each way, and on the discovery of an enemy to fire a Very's signal.

In further preparation, the machine guns and 3-inch howitzer were manned, pumps worked, a judge at each gun (officers of the Naval War College and Torpedo Station), and bright lookouts kept from prominent parts of the ship.

Soon after, the alarm was given from the picket on the port quarter, followed by that on the starboard quarter and both bows, showing that the enemy intended striking on both bows and quarters. Machine guns, howitzers and hose were ready. All the boats of the attacking force were put out, in accordance with the rules, before any damage was done; but, notwithstanding this, several per-

sisted in attacking, one in particular on the port beam making repeated attempts to carry away the defenses, but without success.

The umpire having decided the attack finished, the gun to signify the fact was fired, attacking boats came alongside and reported to the judges, who after consultation decided that the attack was wholly unsuccessful.

A thorough examination of the defense on the morning of the 17th showed that the defenses were intact, without the slightest injury.

I would mention that the boats were not supplied with torpedoes, that only primers were used in our defensive ones, and that our main battery was not fired for fear of accidents.

The Hotchkiss, having no blank cartridges, and the 3-inch not working well with the same, were also not fired, but kept bearing on the attacking boats as they were discovered. Sharpshooters fore and aft on both sides and the Gatling used blank cartridges as the attacking boats came within their vision.

Very respectfully,

Your obedient servant,

ROBT. BOYD, *Captain, Commanding.*

RULES GOVERNING ATTACK BY TORPEDO BOATS AND DEFENSE OF U. S. S. TENNESSEE AGAINST SUCH ATTACK.

Any boat, in the opinion of the judges, that is under fire for fifteen seconds shall be ruled out.

Any boat getting inside of obstructions within twenty feet of hull will be considered as having made a hit.

Any boat claiming a hit will blow a whistle—prolonged blast—and then remain in position, quiet, until decision is announced.

Boats will be assigned a number. When in the opinion of a judge a boat is ruled out, a Very's signal will be discharged in the direction of the boat, and as soon after as possible that boat will answer by blasts of the whistle corresponding to number of boat.

When any boat is ruled out, the officer in charge of boat will immediately withdraw his boat to a reasonable distance and await recall.

At the termination of the exercise a gun will be fired, when all boats will assemble alongside.

A judge at each machine gun.

Decision of judge final.

Differences of opinion by judges to be decided by umpire.

THE REEL LIFE BUOY.

INVENTED BY NAVAL CADET ARMISTEAD RUST, U. S. N.

This buoy is designed to be used on board seagoing vessels of all kinds for the purpose of rescuing in the shortest possible time any person who may happen to fall overboard, and to recover man and buoy without the necessity of lowering a boat. It may also be used to rescue the crew of a ship in distress at sea in heavy weather. The reel is wound with about half a mile of steel wire rope about one-quarter of an inch in diameter. The axle is fitted with a crank at each end, and is mounted to turn with the least possible friction. The reel is fitted with a strap friction-brake, and is mounted on a revolving platform, and may be securely held in any position by a set screw. The buoy is hung below a platform built out over the ship's stern, and is in form of a small life-boat, the bow, stern and sides being air tanks of sheet metal, and the bottom an iron grating. To give stability there is a heavy narrow iron keel which fits up close under the bottom of the buoy when it is suspended at the stern; but when the buoy is detached, this keel drops, and

is held in position some distance below the bottom of the buoy by three iron rods sliding in vertical pipes which are secured in the air tanks and centre of the buoy. There is just space enough in the centre of the buoy to afford standing-room for one man. When suspended at the stern the buoy is held steady in a sea-way by vertical rods which extend down from the platform and pass through pipes in the buoy. On top of the buoy are two metal standards, each supporting a metal box, with cover, for holding the composition known as "port fire." When the buoy is detached the covers are removed automatically, and the lights ignited by friction primers. In one air tank there is a small locker for holding a Very's signal pistol, food, water, etc. On each side of the buoy is a movable fin, which is rigged out at first and remains so until it is desired to reel up, when the fins are rigged in by the man in the buoy. They are to prevent the buoy from being towed until the man overboard gets inside. Electrical connection may be made between the buoy and ship by an insulated copper wire passing through the centre of the wire rope, so that signals can be exchanged in foggy weather, when the lights would not show. The buoy is provided with eye-bolts for hoisting, and suitable life lines. There is also a bottle of oil so arranged as to break when the buoy strikes the water, and a can to furnish a further supply, to smooth the sea in the neighborhood.

The following advantages are claimed:

1. Means of recovering man and buoy without lowering a boat.
2. It is so constructed as to remain practically stationary in the water if so desired.
3. It may be controlled from the ship and hauled up to the man overboard.
4. Means are provided for signalling from the buoy.
5. The man is protected from sharks, and his strength not exhausted by hanging on, and he is provided with food in case the line parts and the buoy cannot be picked up for several days in heavy weather.
6. The buoy is dropped and the lights lighted by moving a single lever, it has great buoyancy and stability, all parts are simple and not liable to get out of order, and it is light and easy to hoist.

REPORT ON EXPERIMENTS MADE TO DETERMINE THE BEST METHOD OF DRYING GUN-COTTON PRIMERS FOR SERVICE USE.

TORPEDO STATION, NEWPORT, R. I., *April* 22, 1885.

Sir:—In obedience to your order, we beg leave to submit the accompanying chart of curves, representing the different methods of drying gun-cotton as called for by our order of November 25, 1884, with remarks upon each curve and the conclusion arrived at by the Board,

We also append the results of analysis made by Mr. J. F. White, chemist, at the request of the Board, to determine what effect, if any, $CaCl_2$ will have upon gun-cotton, wet or dry, exposed to its influences.

Very respectfully,

(Signed) J. S. NEWELL, *Lieut.-Comdr., U. S. N.*
(") E. W. BRIDGE, *Lieutenant,* " " "
(") J. F. WHITE, *Chemist.*

Commander W. T. SAMPSON, *U. S. N.*,
Inspector of Ordnance, in Charge of Station.

CHART OF DRYING CURVES.

Net percentages of water are shown on the left; time (in days) at the bottom and top.

Curve No. 1 shows the result of exposing the discs to the air of a large room warmed by a stove.

Five discs, their average weight being 423.96 grams, were placed on a fine wire screen in the lecture-room of the chemical laboratory, the room being heated by a large stove, for twenty-three days, and their weight noted daily. At the end of the twenty-third day, the discs having ceased to lose weight, two of them were exposed to calcium chloride ($CaCl_2$) under two conditions—*i. e.* in a vacuum and not in vacuum—for twelve days more; and three discs were exposed in a steam dryer for sixteen days (the temperature of the dryer for seven hours each day (9 A. M. to 4 P. M.) averaging between 90 degrees and 100 degrees F.). At the end of these times the discs had all ceased to lose weight and showed an average total loss of $30\frac{6}{10}$ per cent. net.

From this we assume that the average discs originally held 31 per cent. net of water, and that the loss due to exposure to air was equal to 29½ per cent. net. And from the assumption that the discs originally held 31 per cent. net of water, we find the net average weight to have been 323.6 grams.

At noon each day the temperature, wet and dry bulbs, was recorded as follows:

	Room.		Temperature Outside.
January 15	Dry 58 degrees.	Wet 50 degrees	40 degrees.
" 16	" 57 "	" 50 "	35 "
" 17	" 64 "	" 55 "	48 "
" 18	" 54 "	" 45 "	30 "
" 19	" 56 "	" 47 "	31 "
" 20	" 51 "	" 43 "	16 "
" 21	" 58 "	" 48 "	36 "
" 22	" 38 "	" 34 "	16 "
" 23	" 42 "	" 34 "	24 "
" 24	" 54 "	" 45 "	34 "
" 25	" 50 "	" 45 "	40 "
" 26	" 52 "	" 44 "	36 "
" 27	" 43 "	" 36 "	23 "
" 28	" 42 "	" 34 "	20 "
" 29	" 38 "	" 32 "	13 "
" 30	" 55 "	" 47 "	34 "
" 31	" 62 "	" 51 "	45 "
February 1	" 56 "	" 48 "	45 "
" 2	" 52 "	" 41 "	18 "
" 3	" 51 "	" 42 "	28 "
" 4	" 55 "	" 45 "	32 "
" 5	" 64 "	" 53 "	44 "
" 6	" 45 "	" 38 "	24 "
" 7	" 44 "	" 36 "	28 "

Curve No. 2 shows the result of exposing the discs in an outhouse with no artificial heat.

Ten (10) discs were taken and placed in an outhouse January 2, 1885, where they were sheltered from storm or bad weather, and only exposed to the air of the house. No current or draught of air or artificial heat. The ventilation of the house was obtained only when the doors were opened, and of these there were two, one inside the other. The house was practically sealed up. From time to time the discs were removed from the house to the laboratory, where they were weighed and then returned.

Curve No. 3 shows the result of piercing the discs with a number of holes similar to the one required for all primers to be used in the contact torpedoes, and exposing them to the air of a large room warmed by a stove.

Five (5) discs, each having six holes bored through them, were placed upon a fine wire screen so that the discs had air space all around. The discs were subjected to the same treatment as those represented by Curve No. 1, the average gross weight being 420.4 grams, and when dry showing an average loss of $34\frac{2}{3}$ per cent. net. We assume that originally they held 35 per cent.

net of water, and that their loss due to exposure in the room was equal to $33\frac{6}{10}$ per cent. net. From the assumption that the discs originally held 35 per cent. of water, we find their net weight to have been 311.4 grams. The temperatures are recorded with Curve No. 1.

(Note.—This curve should have its origin at 35 per cent., and after the fifth day will conform very nearly with Curve No. 1.)

Curve No. 4 shows the result of exposing the discs in the hot air of the steam dryers.

Four discs, their average gross weight being 412.4 grams, were placed in a steam dryer, service pattern, the steam being supplied from a cylindrical boiler (about one foot by one foot) placed on a stove in an adjoining room. Steam was supplied from 9 A. M. to 4.30 P. M. daily, the temperature of the dryer being noted every hour. The dryer was run daily until the discs ceased to lose weight. The discs were weighed daily at noon, and the temperature of the open air (out-doors) was noted. On the twelfth day it was found that the average loss during the preceding 24 hours was one-fifth of one per cent., and the discs were removed. The total average loss was found to be 33.6 per cent. net. From this we assumed that the average discs originally held 34 per cent. net of water, which gave a net weight for the discs of 308.6 grams.

The average temperature for the dryer, while in operation each day, as well as the temperature of the open air at noon, is shown in the following table:

	Average Temperature of Dryer for 7½ hours, 9 A. M. to 4.30 P. M.	Temperature Outside at Noon.
March 30	102 degrees F.	56 degrees.
" 31	103 "	54 "
April 1	107 "	56 "
" 2	107 "	46 "
" 3	107 "	58 "
" 4	102½ "	40 "
" 5	98 "	42 "
" 6	107½ "	50 "
" 7	100 "	61 "
" 8	106 "	49 "
" 9	107 "	44 "
" 10	107½ "	58 "
" 11	108 "	56 "

To obtain a comparison between the use of the boiler mentioned and the one issued with a dryer, one of each was put in operation and continued for several days, the result giving an average temperature for the service boiler of 96.8 degrees, and for the one used in experiment 97.8 degrees.

Curve No. 5 shows the result of exposing the discs to $CaCl_2$ (calcium chloride), the tank being frequently opened and the air not exhausted.

Four (4) discs, their average gross weight being 391.7 grams, were treated as those in Curve No. 9, except that the air was not exhausted. The tank was opened on the fourth, eighth, twelfth, sixteenth, twentieth, twenty-third, twenty-fifth, twenty-sixth, twenty-seventh, twenty-eighth and twenty-ninth days, the discs weighed and the $CaCl_2$ dried. It was found that after the twenty-fifth day the discs did not lose weight, and on that day the total loss amounted to $30\frac{1}{2}$ per cent. net. From this we have assumed that the average discs originally held 31 per cent. net of water, which would give the discs a net weight of 299 grams.

Curve No. 6 shows the result of exposing the discs to $CaCl_2$ (calcium chloride), the tank being seldom opened and the air not exhausted.

Four (4) discs, their average gross weight being 398.9 grams, were treated in a manner similar to those of Curve No. 9, except that the air was not exhausted and the tank was first opened on the sixteenth day and on the twentieth, twenty-third, twenty-fifth, twenty-sixth, twenty-seventh, twenty-eighth

and twenty-ninth days, the discs being weighed and $CaCl_2$ dried. It was found that the discs practically ceased to lose weight after the twenty-fifth day, and on that day the loss amounted in all to 32⅔ per cent. net. From this we assume that the average discs originally held 33 per cent. net of water, which would give a net weight for the discs of 300 grams.

Curve No. 7 shows the result of exposing the discs to the sun in the open air.

Five (5) discs were exposed to the sun, and, when the sun was not shining, kept in a closed box in the chemical laboratory, which building was warmed by a stove. These discs, when exposed to the sun, rested upon a shellaced board and were placed under the shelter of a bank. The experiment began December 30th, 1884, and was continued 45 days, ending February 13th, 1885. During this time the discs were weighed before and after exposure. At the end of the 45 days the discs ceased to lose weight.

Average gross weight, 432 grams.

Exposed to sun 165 hours,		suffered loss	68.3 grams.
Not " " " 919 "		" "	25.7 "
Total,	1084 "	" "	94
	45⅛ days,	" "	285 per cent. net.
	Leaving in discs		25 " "
			31 " "

A record of weather and temperature during this time is appended:

RECORD OF TEMPERATURE AND WEATHER, DISCS EXPOSED TO THE SUN.

Day.	Temperature Noon.	Weather.	Wind.
Dec. 30.	60 degrees.	Clear, pleasant and mild.	Moderate southward and westward.
Jan. 2.	23 "	Clear and cold.	Fresh northward.
" 3.	23 "	Clear, cold and pleasant.	Light airs northward.
" 5.	41 "	" " " "	" " westward.
" 8.	44 "	Fresh and pleasant.	" " northw'd and westward.
" 9.	52 "	Cloudy " "	Fresh southward.
" 10.	36 "	Clear and cold.	Strong westward.
" 13.	38 "	Clear and pleasant.	Fresh northward.
" 14.	39 "	" " "	Light northward.
" 19.	31 "	" " cold.	Northwest.
" 20.	29 "	" " "	Northwest.
" 21.	36 "	" " pleasant.	Strong southward and westward.
" 22.	16 "	" " cold.	Strong northward.
" 23.	24 "	" " "	
" 26.	36 "	" " "	Fresh northwest.
" 27.	23 "	" " "	Light northwest.
" 29.	13 "	" " "	
" 30.	34 "	" " "	
" 31.	45 "	" " pleasant.	
Feb. 2.	18 "	" " cold.	Strong northwest.
" 3.	28 "	" " "	Light airs northwest.
" 7.	28 "	" " pleasant.	Northward and westw'd.
" 11.	10 "	" " cold.	Northwest.
" 12.	21 "	" " "	Light northward and westward.
" 13.	34 "	" " cloudy.	Northward and eastward.
" 14.	28 "	Clear.	Northeast.

RECORD OF TEMPERATURE AND WEATHER, DISCS NOT EXPOSED TO THE SUN.

Day.	Temperature Noon.	Weather.	Wind.
Dec. 31.	48 degrees.	Mild, foggy.	Southward.
Jan. 1.	45 "	Cold and rainy.	
" 4.	34 "	Cloudy, snow and rain.	
" 6.	50 "	Rain.	Eastward.
" 7.	45 "	Cloudy, mild.	Southwest.
" 11.	40 "	Cloudy and cold.	
" 12.	50 "	Rain.	Strong southwest.
" 15.	40 "	Rain.	Southward and eastward.
" 16.	35 "	Rain.	
" 17.	48 "	Cloudy.	Moderate gale southwest.
" 18.	30 "	Clear and cold.	Northward.
" 24.	34 "	Stormy, snow and rain.	
" 25.	40 "	Cloudy, damp rain.	
" 28.	20 "	Cold, snow.	
Feb. 1.	35 "	Rain and snow.	Variable.
" 4.	32 "	Cold and foggy.	
" 5.	44 "	Cloudy, clear.	Light airs westward.
" 6.	24 "	Snow, cloudy, sleet.	Fresh northward.
" 8.	28 "	Cloudy, snow, sleet.	
" 9.	40 "	Cloudy and damp.	Eastward.
" 10.	42 "	Foggy.	

Curve No. 8 shows the result of exposing the discs to $CaCl_2$ (calcium chloride) in a vacuum, the tank being seldom opened.

Four (4) discs, their average weight being 398.1 grams, were exposed under the same conditions as those discs in Curve No. 9, with the exception that the tank was opened for the first time on the eighteenth day. The operation was continued for twenty-three days, when it was found that the discs had lost on the average less than .1 of a gram since the twentieth day, and the average total loss had been 29.8 per cent. net. From this we assume that the average discs originally held 30 per cent. net of water, which gave a net weight for the discs of 306.2 grams.

Curve No. 9 shows the result of exposing the discs to $CaCl_2$ (calcium chloride) in a vacuum, the tank being opened frequently.

Four (4) discs, their average gross weight being 400.9 grams, were placed in an ordinary powder tank, over and near to, but not in contact with, one thousand (1000) grams of $CaCl_2$ in a round tin pan. The air was exhausted from the tank. Every four (4) days the tank was opened and the $CaCl_2$ dried by exposure in the oven of an ordinary cooking-stove and then replaced in the tank. The discs were weighed whenever the tank was opened. At the end of the twenty-third day, it being very difficult to maintain a vacuum, and the discs having lost less than one (1) gram each since the twentieth day, this plan was discontinued, and it was found that the average loss had been 31.8 per cent. From this we have assumed that the average discs originally held 32 per cent. net of water, as shown by the curve, which gave a net weight for the discs of 303.7 grams.

Curve No. 10 shows the result of exposing the discs to the atmosphere day and night continuously for forty-six days.

Fifteen (15) discs were placed in a 15-inch cubical wooden box upon two shelves that divided the box into three parts. The shelves and sides of the box were pierced with a number of ½-inch holes, in order to allow a free circulation of air. The cover of the box projected on all sides and was made watertight. The box was placed upon the embankment to the west of the chemical laboratory, where it was partially sheltered by the parapet to the westward. The discs were exposed from the 23d of December, 1884, to the 16th of Feb-

ruary, 1885. During this time they were weighed at short intervals, and six (6) of them found to have become saturated in the violent storms that prevailed. Taking the remaining nine discs, whose average gross weight was 431.8 grams, and assuming that they originally held 31 per cent. net of water, we found that in forty-six days the average loss had been 24 per cent. net, as shown by the curve. The average net weight of these discs, assuming 31 per cent. of water, was 329.6 grams.

The weather average during the forty-six days is shown in the following table:

Date.	Tempt'e Noon.	Weather.	Wind.
Dec. 23.	23 degrees.	Cloudy, but dry.	Westward.
" 24.	23 "	Cold, with snow.	"
" 25.	25 "	Cold and cloudy.	Northward and eastw'd.
" 26.	26 "	Cold and cloudy.	Northward.
" 27.	26 "	Cold, moderating.	Northward and eastw'd.
" 28.	38 "	Mild and foggy.	" "
" 29.	44 "	" " "	Southward and westw'd.
" 30.	60 "	Clear and pleasant.	" "
" 31.	48 "	Mild and foggy.	Southward.
Jan. 1.	45 "	Cold and rainy.	
" 2.	23 "	Clear and cold.	Northward.
" 3.	23 "	" " "	"
" 4.	34 "	Cloudy, snow and rain.	
" 5.	41 "	Clear and pleasant.	
" 6.	50 "	Steady rain.	East.
" 7.	45 "	Cloudy and mild.	Southwest.
" 8.	44 "	Clear and pleasant.	Northward and westw'd.
" 9.	52 "	Cloudy, but pleasant.	Southward.
" 10.	36 "	Clear and cold.	Westward.
" 11.	40 "	Cloudy and cold.	
" 12.	50 "	Rain.	Southward and westw'd.
" 13.	38 "	Clear and pleasant.	Northward.
" 14.	39 "	" " "	"
" 15.	40 "	Rain.	Southward and westw'd.
" 16.	35 "	"	
" 17.	48 "	Cloudy, but clearing.	Southward and westw'd.
" 18.	30 "	Clear and cold.	Northwest.
" 19.	31 "	" " "	"
" 20.	29 "	" " "	"
" 21.	36 "	Clear and pleasant.	Southward and westw'd.
" 22.	16 "	Clear and cold.	Northward.
" 23.	24 "	" " "	
" 24.	34 "	Stormy, rain and snow.	
" 25.	40 "	Cloudy and damp, little rain.	
" 26.	36 "	Clear and cold.	Northwest.
" 27.	23 "	" " "	"
" 28.	20 "	Cold and snowing.	
" 29.	13 "	Clear and cold.	
" 30.	34 "	" " "	
" 31.	45 "	Clear and pleasant.	
Feb. 1.	35 "	Rain and snow.	Variable.
" 2.	18 "	Clear and cold.	Northwest.
" 3.	28 "	" " "	"
" 4.	32 "	Cold, damp, foggy.	
" 5.	44 "	Cloudy.	Northward.
" 6.	24 "	Snow, cloudy, cold.	"

Date.	Tempt'e Noon.	Weather.	Wind.
Feb. 7.	28 degrees.	Clear and pleasant.	Northward and westw'd.
" 8.	28 "	Cloudy, snow and sleet.	
" 9.	40 "	Cloudy and damp.	Eastward.
" 10.	42 "	Damp and foggy.	
" 11.	10 "	Clear and cold.	Northwest.
" 12.	21 "	" " "	Northward and westw'd.
" 13.	34 "	Clear and cloudy.	Northward and eastw'd.
" 14.	28 "	Clear.	Northeast.
" 15.	31 "	Clear and pleasant.	Northward and eastw'd.
" 16.	34 "	Overcast and heavy rain.	Southward and eastw'd.

To ascertain the relative value of the following methods of drying wet gun-cotton discs—viz.: by—first, exposure in a dry room; second, exposure to calcium chloride: *a*, air exhausted; *b*, air not exhausted; third, exposure in steam dryer.

Five (5) discs whose average gross weight was 420.2 grams were exposed for twenty-three days to No. 1, from December 23, 1884, to January 14, 1885, when they ceased to lose weight.

The same discs were placed in No. 2*a* for twenty-two days, January 16 to February 7, 1885, and having ceased to lose weight while thus exposed, were exposed to No. 3 for twelve days, February 9 to 21, 1885; the temperature of the dryer from 9 A. M. to 4 P. M. daily except Sunday averaging ninety-six degrees F.

Five (5) discs whose average gross weight was 420.2 grams were subjected to the same treatment, except that the $CaCl_2$ (calcium chloride) was not in a vacuum. Two of these discs whose average gross weight was 427.5 grams were then exposed to No. 1 for twenty-three days, then to No. 3 for twenty-three days, and finally to No. 2*a* for twelve days.

Two (2) of these discs whose average gross weight was 423 grams were also subjected to the same treatment and in the same sequence, except that the $CaCl_2$ (calcium chloride) was not in a vacuum.

Tabulating the results for comparison, we will have:

AVERAGE WEIGHT OF DISCS AFTER BEING EXPOSED.

Gross. Av. Wt.	23 Days Air.	22 Days $CaCl_2$.	12 Days Dryer.	Net Wt. Dry.
No. 1, 420.2	326.46	320.93 vac.	321.3	320.93
" 2, 420.2	323.18	316.9	317.67	316.9
		22 Days Dryer.	12 $CaCl_2$.	
" 3, 427.5	336.85	331.75	331.65 vac.	331.65
" 4, 423	335.65	329.15	329.35	329.15

Showing that in every case except the last $CaCl_2$ extracted more moisture than the other methods; also that the vacuum possesses no practical advantage.

The first two cases show that after the discs had ceased to lose weight in the air, they continued to lose when exposed to $CaCl_2$, the loss amounting to nearly 2 per cent. net; and also that the discs, after they had ceased to lose weight by the $CaCl_2$, gained slightly when exposed to the steam dryer.

The last two cases show that after the discs had ceased to lose weight in the air, they continued to lose weight when exposed in the steam dryer, the loss amounting to nearly 2 per cent., and after ceasing to lose weight in the dryer, that when exposed to $CaCl_2$ they lost very slightly in a vacuum, and gained very slightly not in a vacuum.

From this it appears that the same results are ultimately obtained by the use of either steam dryer or $CaCl_2$.

We found that the discs of gun-cotton made at this station contained after final pressure about 15 per cent. net of water; and as it is the custom before packing discs for issue to allow them to remain in an alkali solution for ten (10) minutes, that the discs as issued to the service contain from 30 to 35 per cent. net of water; also that a disc two (2) inches in height contains 315.6 grams of gun-cotton, or about 11.132 ounces avoirdupois.

We consider that of all the different methods pursued to dry wet gun-cotton discs, the following give the best results—viz.: No. 1, exposure to a dry atmosphere; No. 2, exposure to $CaCl_2$; No. 3, exposure in a steam dryer.

The third method will expel the largest percentage of moisture in the least time.

The second method requires twice the time of No. 3 to expel the same percentage of moisture.

The first method, in twice the time required by No. 2, and four times that of No. 1, will still retain at least 2 per cent. of water, which under methods Nos. 2 and 3 would entirely disappear.

Whether it is necessary, in order to obtain complete detonation, that discs for primers should contain less than 2 per cent. of water, we are not at present prepared to state.

The third method requires constant care and attention, a special place, and is attended with more or less risk, which conditions do not commend this plan to the Board for use on board ship.

The first method requires care and a suitable place on shipboard, which conditions can be easily fulfilled. This plan is only available in dry climates, and climatic changes will seriously interfere with it.

The second method requires but little care and attention and is independent of location and atmospheric conditions. The gun-cotton is, while drying, excluded from the action of light, which is to be desired. Calcium chloride ($CaCl_2$) has no effect upon gun-cotton as shown by the analysis appended, except when brought into absolute contact for great length of time (a condition that will never obtain in drying). Although the Board gives the preference to the second (or $CaCl_2$) method, they are of the opinion that both the first (air) and the second ($CaCl_2$) methods should be allowed, and submit the following rules:

Drying by Exposure in a Dry Atmosphere.

String the discs to be dried on a brass or copper rod or pipe, which should be free from dirt and *oil;* separate the discs from each other to expose all the surfaces freely to the air; suspend the rod in some suitable place—not in the vicinity of the galley or boilers—where the discs will be freely exposed to the air and be under cover (the span of the stern or quarter boat davits, or the spanker boom, with an awning or similar shield over them, will answer the purpose). Expose the discs only when the atmosphere is dry; at other times the discs should be kept in an empty powder tank, which can be kept in the immediate vicinity of the place selected for drying, and kept close to exclude moisture. Weigh the discs every two days, noting the date and weight on the side of the discs with a soft lead pencil. Continue the drying until the discs show no loss of weight for two consecutive weighings, then place the discs in the glass jars, with strips of blue litmus paper between the discs, and treat them according to the rules given for drying gun-cotton primers.

Drying by Exposure to Calcium Chloride ($CaCl_2$).

This method requires 5 pounds chloride of calcium or calcium chloride (Ca Cl_2), 1 empty powder tank, 3 baking-pans.

Chloride of calcium or calcium chloride ($CaCl_2$) is cheap, and can readily be obtained from any dealer in chemicals. It should not be confounded with chloride of lime or bleaching powder (CaO_2Cl_2). The latter has a strong odor of

chlorine, and if used instead of the chloride of calcium ($CaCl_2$) might cause decomposition of the gun-cotton. Chloride of calcium ($CaCl_2$) is odorless and has no bleaching properties.

To distinguish whether the substance has any bleaching properties, stir a small portion in an equal volume of water and immerse a piece of blue litmus paper in the mixture; if the color disappears from the paper when dry (turning white), the substance is chloride of lime or bleaching powder (CaO_2Cl_2), and should not be used.

The powder tank can be readily procured on board ship. Care should be taken that it closes easily. The baking-pans should be of such a size that three of them will cover the bottom of the tank when placed alongside of each other, made of stout tin, free from solder, and five to six inches deep. (For the powder tank, model of 1854, these pans should be twelve inches long, four inches wide and five inches deep; this size can readily be entered through the mouth of the tank.)

Divide the calcium chloride between the three pans and place these pans, which should be clean, free from oil or grease, in the oven of the galley and allow them to remain there until all traces of moisture have disappeared from the calcium chloride. Stir the calcium chloride occasionally with a clean metal rod to expose the lower particles. Break the calcium chloride into pieces size of a pigeon's egg. When all traces of moisture have disappeared remove the pans to a dry place and allow them to cool. The calcium chloride should not be put in the tank while warm, or the gun-cotton exposed to it. Place the tank in some suitable location where it will not be disturbed (shaken about), as the calcium chloride may be spilled out of its pans. When the calcium chloride is cooled off place the pans on the bottom of the tank and lay over the pans a copper sieve (tinned copper wire is the best) or the racks from the steam dryer. Then place the discs to be dried on the sieve or racks and close the tank. Open the tank every three or four days, weigh the discs and dry the calcium chloride as before. Mark the weight and date with a soft lead pencil on the side of the discs. Continue this until the discs have ceased to lose weight. While the calcium chloride is drying, the discs can be kept in the tank, which should be closed, to exclude the moisture in the air. When the discs have ceased to lose weight, store them in the glass jars, with strips of blue litmus paper between the discs, and observe the rules laid down for dry gun-cotton primers.

This operation is independent of the conditions of the atmosphere and only requires the care mentioned.

The following experiments were conducted and heat tests made in order to determine the influence of calcium chloride upon the stability of gun-cotton:

Well-prepared gun-cotton will not liberate a trace of acid when exposed to a constant temperature of 150 degrees F. for 12½ minutes. This constitutes the English "heat test."

One disc of gun-cotton was divided into two parts, one of which was packed in a glass jar with fused calcium chloride in such a way that the chloride was in direct contact with and completely covered the gun-cotton; while the other was simply placed in a similar clean glass jar, and after closing both to exclude moisture they were stored in an outhouse for eighty-five days. The gun-cotton at the end of this time showed no external change, and that packed in calcium chloride stood a constant temperature of 150° F. for 21½ minutes before acid reaction was detected; while that stored without the chloride stood the same test for 23 minutes.

One disc of wet gun-cotton was buried in fused calcium chloride contained in a wooden box and stored same as above for ninety-two days. At the end of this time the disc was removed, and a sample gave acid reaction when exposed for 20 minutes to a constant temperature of 150° F.

A sample taken from a gun-cotton disc which had remained for twenty-three days in a vacuum, and over, but not in contact with, calcium chloride, gave

acid reaction after an exposure of 22 minutes to a constant temperature of 150° F.

Another sample, taken from a disc dried same as the last described, except that air repeatedly leaked into the tank in which it was stored, stood heat test for 29½ minutes.

Other gun-cotton discs were dried in a closed powder tank, and over, but not in contact with, fused calcium chloride. The air was not exhausted from the tank, but the chloride was frequently removed and fused. A sample taken from these discs after being stored as above described for twenty-six days withstood a temperature of 150° F. for 20 minutes before acid reaction was observed.

Another sample, taken from discs dried in the same way as the last described, except that the chloride was not fused during the twenty-six days, gave the same results when exposed to the heat test.

A sample taken from a disc that had been exposed to the air for twenty-three days, and afterwards dried over calcium chloride in a closed powder tank for sixteen days, withstood a temperature of 150° F. for 18 minutes before acid reaction could be detected.

A sample taken from a disc dried in the same manner as the last described, except that the air was exhausted from the powder tank, stood the heat test for 17½ minutes. A sample of gun-cotton pulp taken from a well-prepared and well-washed charge was saturated with a concentrated aqueous solution of calcium chloride; after drying, it withstood a temperature of 150° F. for 23 minutes.

Another sample, taken from the same charge and prepared in the ordinary way, gave the same results when subjected to the heat test.

BAIRD'S AUTOMATIC STEAM TRAP.

The following is an abstract from the report made to the Bureau of Steam Engineering by a board consisting of Chief Engineers Devalin and McCartney, and Passed-Assistant Engineer Leitch, upon the merits and demerits of a steam trap invented by Passed-Assistant Engineer G. W. Baird, U. S. N., and used on board the United States Fish Commission steamer Albatross:

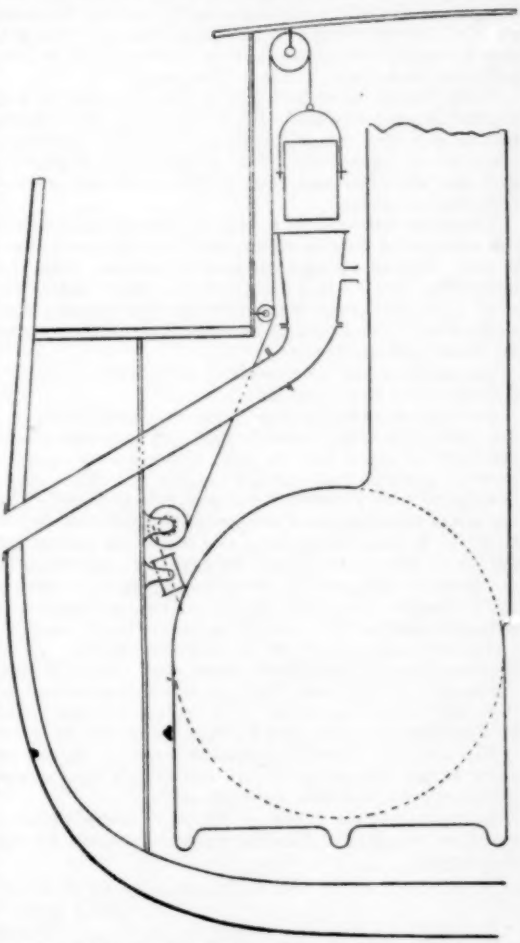
"The trap consists of a cast-iron chamber containing a spherical hollow float, a bell-crank lever and a piston valve. The float is made of glass and is six inches in diameter outside. The inventor does not confine himself to glass, but claims the use of a metal sphere for the same purpose. The piston valve and valve chamber are of brass, and the valve has an opening of one-half of a square inch. The condensed water from the radiators enters the trap on top, and on rising to a given level lifts the float, and, by means of the levers, opens the piston valve for the discharge of the water. When the water level falls to a certain point the valve closes and prevents the escape of steam. There is an attachment for opening and closing the valve by hand. The advantages are: The employment of a piston valve, perfectly balanced, for the discharge; certainty of action; small space occupied; cheapness; lightness; it is automatic; has a large opening for discharge; can be shut off or blown through by the hand attachment. The disadvantages are those common to all traps having closed hollow vessels for floats, which sometimes leak and fill with water, and also that the piston valve will in time become leaky from wear in one direction. We recommend its purchase and use on naval vessels."

W. F. W.

THE ASH-HOIST OF THE U. S. STEAMSHIP ALBATROSS.

By G. W. BAIRD, Passed-Assistant Engineer, U. S. N.

The demand for a convenient, economical and cleanly ash-chute has existed ever since steam was introduced on board ship. In carrying ashes over the decks, let ever so great care be taken, part will be spilled, which not only soils but cuts and scars the planking. The labor of hoisting the ashes, the loss of time, and the inconvenience to those on deck, are well known, while to those in the fire-room is experienced a still greater annoyance; for, as is often the case, when the fires are cleaned and the ashes ready to hoist, the sailors are at work which is considered more important, and the ashes must wait; with several banks of ashes in the fire-room, it is difficult to get at the fires to stoke them, and, as a result, the steam pressure falls, and the speed of the ship is reduced.



While superintending the building of the Albatross, in 1882, the writer designed a hoist and chute (see Fig.), which was built by the Pusey & Jones Company, which has worked well, and is herein described, with a hope that this or some better arrangement may be utilized in the new Navy. The object of the chute and hoist is to provide simple, effective and economical means of ejecting the ashes without carrying them over the deck. Before describing the device it will be proper to note other machines which have been used in the Navy and abandoned.

The *stand-pipe*, a vertical plate-iron cylinder, was placed in the fire-room of the Neptune in 1863, its lower end being flanged and bolted to the bottom planking, its upper end extending several feet above the water line. Both ends were open. The ashes were dumped into this chute with a copious current of

water, and were washed out through the bottom. It was found on this ship, and on the iron merchant ships using the same device, that the ashes scoured the bottom of the ship in wake of the chute so badly as to wear through the plating in a short time.

A steam ejector was applied on board the Alaska in 1869. The ashes were fed into a hopper, whence they were carried by a steam jet through a chute, passing upward and through the side of the ship. It worked admirably, so far as ejecting the ashes was concerned; but the cinders, moving at such velocity, scoured out the chute in a few days; the cast-iron elbows, where the abrasion was greatest, were increased in thickness up to two inches, which was not sufficient, and the device was abandoned.

"Two hands from each part of the ship man the ash-whip!" was again taken up, and is sung still on board many of our war vessels. If all the men respond except one, the rest will wait for that one and will "growl" until he comes, heedless of emergency. The officer of the deck, with enough else to do, must give his attention and time to this most unmilitary proceeding, if he wants it executed promptly.

The hoist represented in the engraving eliminates these troubles, and though the writer sees details which could be improved, the device has stood the test of time without a single instance of failure. The chute is made of a ten-inch boiler flue, riveted to a flange on the ship's side, and surmounted with a hopper. The chute runs diagonally through the ship's side, and discharges about a foot above the water. A stream of water from a one-and-a-quarter-inch nozzle plays into the hopper.

The engine has an automatic stop which brings it to rest when the bucket arrives at the end of its path.

One man fills the bucket on the fire-room floor and starts the engine to hoist; the other man empties the bucket and starts the engine to lower. The ashes are thus delivered into the sea, about a foot above the load-water line, and they are projected far enough to clear the ship's side at all times. The hopper is covered with a cast-iron lid on a rubber joint. The air in the hopper, above the water entering the chute, must be displaced before any water can enter the ship; so in practice we have not found the rubber joint necessary, and permit the air to come and go past the crevasses under the lid, and we find the weight of the lid is sufficient, in the worst weather, to keep it down without the bolts.

The engine is without gearing; the cast-iron drum, five inches external diameter and twelve inches long, is the crank shaft; a steam cylinder of four and a half inches diameter of bore and seven and a half inches stroke of piston is placed at each end of the drum, with cranks at right angles; the motion of the engine is slow, and although it is bolted to the iron plating of a coal bunker, it is rarely heard on deck. The engine belongs to that class which is reversed by changing its ports, and a single valve acts as throttle and reverse valve.

The Advisory Board adopted this system for the Dolphin, but put a sliding valve at the foot of the chute; the engine they adopted for the hoist is of a different type, but does its work well.

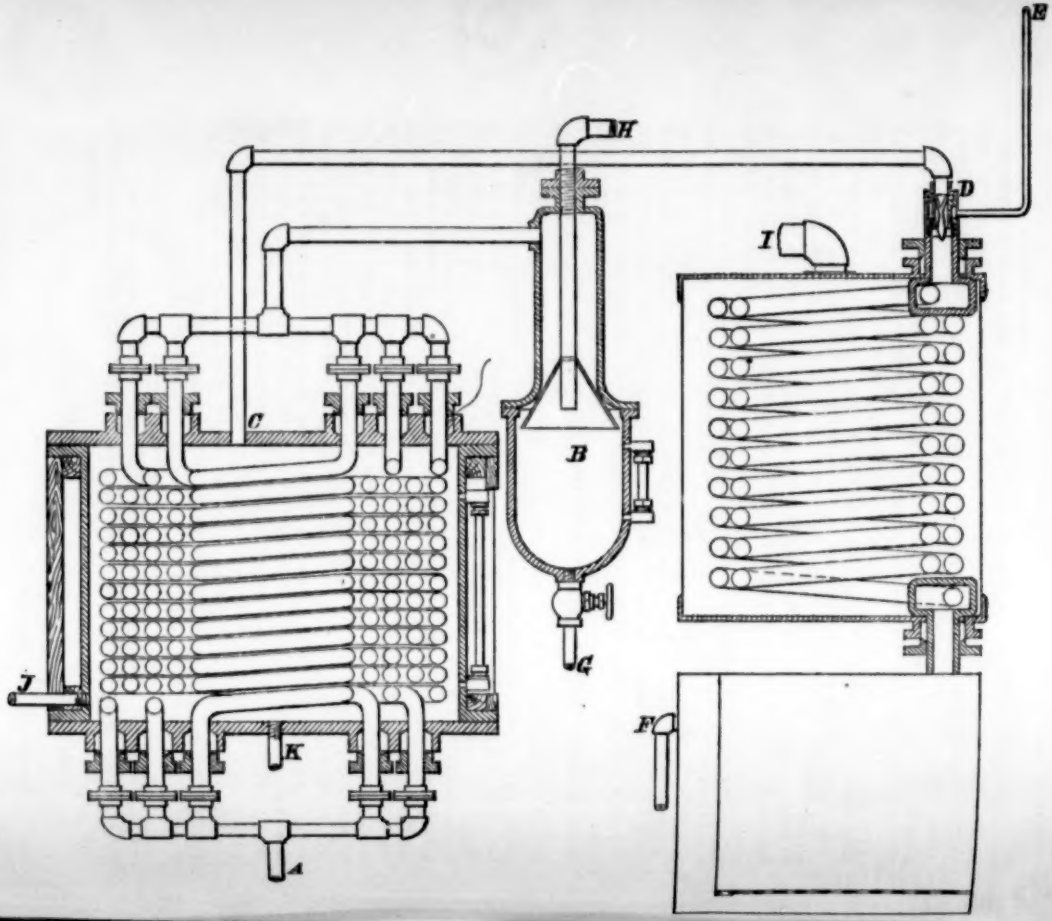
In presenting the plans to the Navy Department for its consideration, the writer enclosed the following testimonial from the commanding officer of the Albatross:

U. S. COMMISSION OF FISH AND FISHERIES,
STEAMER ALBATROSS,
WASHINGTON, *May* 28, 1886.

Captain JOHN G. WALKER, U. S. N.,
President of Board on Additional Cruisers.

Dear Sir:—I approve and forward the enclosed letter calling attention to the ash-chute in use on board this vessel, and endorse all that Mr. Baird claims for it.

The time-honored cry of "Man the ash-whip!" or the more modern rattle of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cog-wheels and chain-whip of the ash-hoist are traditions only on board the Albatross, and I trust for the convenience and comfort of the service that this or some equally good device may be introduced into our new vessels.

Very respectfully,

Z. L. TANNER,
Lieutenant-Commander U. S. N., Commanding.

DISTILLING APPARATUS FOR THE NEW CRUISERS.

The difficulties encountered from the use of mineral oil in steam cylinders, in its distillation from the main boilers on board our ships of war, are aggravated more and more as the boiler pressures are increased. The oil finds its way into the boilers through the condenser, air pump and feed pump.

To completely obviate this difficulty a separate boiler has sometimes been employed, in which clean sea-water alone is used; but in the new ships of war, where it is essential to diminish weight as much as possible, all the boilers must be used, in order to get the regulation two-thirds power; the full power requiring the use of the blast. When a quantity of atmospheric air is introduced into the steam before its condensation, much of the organic matter is oxidized, and may be removed by a special filter. Much of the volatile portion of the oils escapes with the excess of air which is forced into the water, and the remainder finally vaporizes from the tanks or is precipitated. The higher temperatures now used in the boilers are more destructive to the cylinder oils, and make it essential to resort to one of two alternatives—viz.: to use a separate boiler to distil from, or use large tanks which would give the water time to "age." The latter process is out of the question, as neither room nor weight will be accorded for that purpose. Another objection to distilling from the main boilers is that the solid matter in the sea-water (which is a non-conductor), precipitated upon the heating surfaces of the boilers, would soon cause the metal to burn. The thickness of metal in the modern high-pressure boilers is much greater than in the old (low-pressure) boilers, and the transmission of heat through the metal is correspondingly retarded; this is aggravated by the more rapid combustion now employed.

To meet these requirements Passed-Assistant Engineer Baird (the patentee of the fresh-water distiller) has designed an evaporator to take the place of the boiler in his process, which we illustrate.

The coils of the evaporator are of commercial wrought-iron pipe; each coil is in one piece, and there are no joints inside of the apparatus. Steam from the main boilers enters at *A*, and is discharged into the separator. The entrained water is discharged from the separator through *G*, into the hot-well of the main condenser, from *H;* steam is supplied to the donkey pump, which circulates for the distiller (condenser). Thus a circulation is kept up through the evaporator which insures it against "banking up" air, as often occurs in steam heaters.

Sea-water is forced into the evaporator at *J*, the coils being kept nearly covered; this sea-water is vaporized by the heat of the coils; the steam is discharged at *C*, and passes though the aërator *D*, when it induces a current of atmospheric air; and thus the mixed air and steam are delivered to the condenser coils. The condenser coils are made of drawn brass pipes, and are covered with a coating of Banca tin, so that the condensation takes place on a tin surface. Sea-water is kept circulating around these coils (by a circulating pump not shown), and is discharged at *I;* from this discharge—which is warm—the feed supply of the evaporator is taken. The air supplied to the evaporator is conveyed through the pipe *E* from the atmosphere above decks. The condenser is made of brass, the heads three-eighths and the shell one-eighth

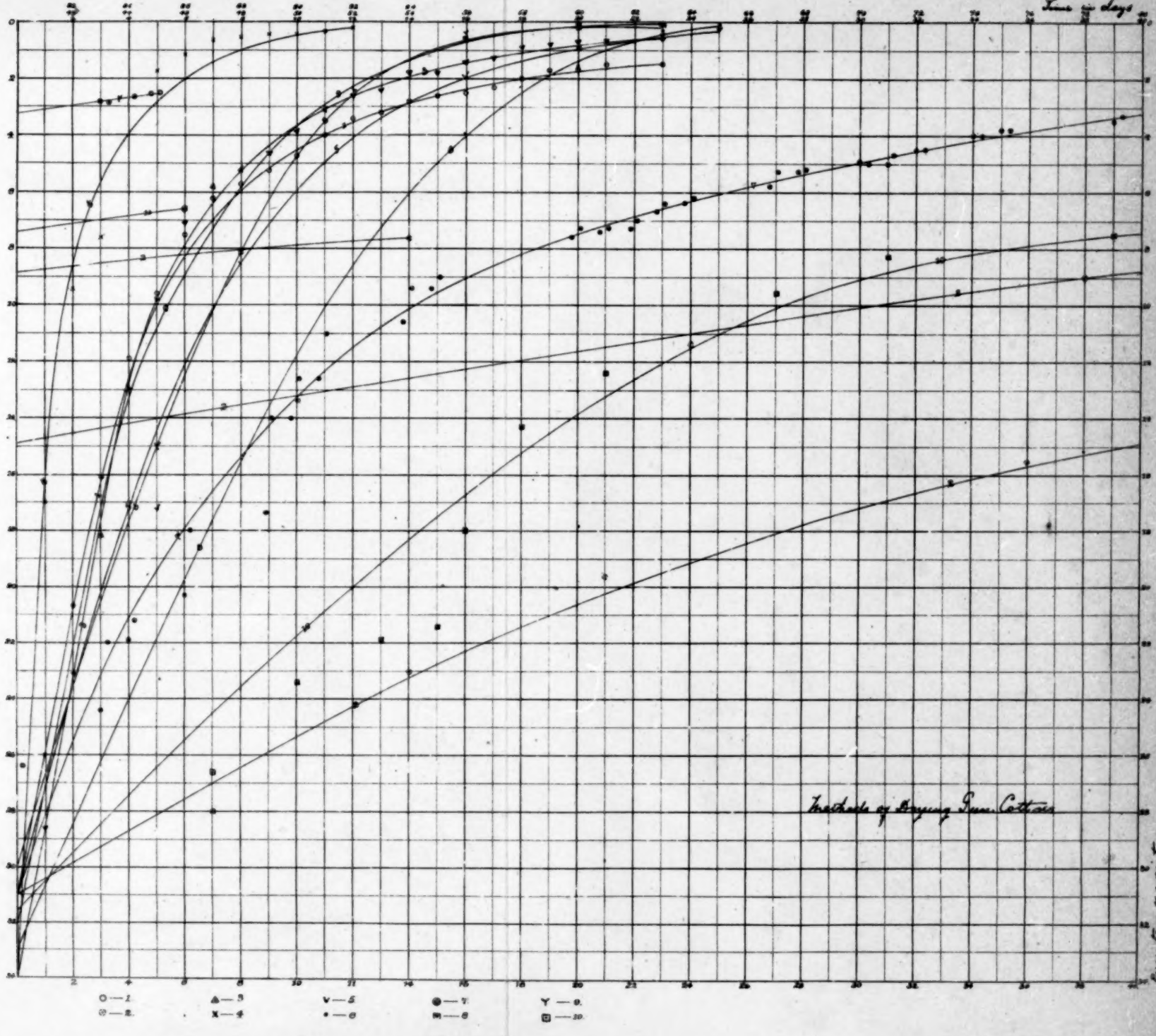
of an inch thick; the filter is of galvanized iron No. 22 w. g. thick. The evaporator will be fitted with a salinometer arrangement. It is believed that a constant feed and blow can be so regulated that the apparatus will require but little attention; the pumps and steam connections may all be operated from the engine-room. The evaporator is so designed that the coils may be removed separately for scaling, which will require to be done about twice a year. Considerable weight and space are saved over the old arrangement, and pure water is insured.

Armored Vessels.		Keel laid. Date.	Launch. Date.	Condition.	Material.	Displacement.	Length.	Beam.	Draught. Mean.	Speed.	I. H. P.	Ar (All hav B
Puritan	Delaware Iron Shipbuilding Co., Chester	1875	...	Completing.	Iron.	6000	280′	60′	18′	13.¼	4100	4.10½″
Miantonomoh	Chester	1874	..	do.	do.	3887	250′	55′6″	14′2″	10.5	1426	4.10″
Amphitrite	Harlan & Hollingsworth, Wilmington	1874	...	do.	do.	3887	250′	55′6″	14′2″	10	1600	4.10″
Monadnock	San Francisco	1874	...	do.	do.	3887	250′	55′6″	14′2″	10	1600	4.10″
Terror	Cramp, Philadelphia	1874	...	do.	do.	3887	250′	55′6″	14′2″	10	1600	4.10″
Armored Cruiser No. 1	Not yet designed	...	...	.	Steel.	6000	...	...	...	17	...	4.10″ 6.6″
do. do. No. 2	do.	...	...	.....	do.	6000	...	...	...	17	...	2.12″ 6.6″
Unarmored Vessels.									Maximum.			
Chicago	Roach, Chester	1883	1886	Completing.	do.	4500	315′	48′2″	20′6″	15	5000	4.8″ 8.6″
Boston	do.	1882	1885	do.	do.	3000	270′	42′	18′6″	14	3500	2.8″ 6.6″
Atlanta	do.	1882	1885	Commissioned.	do.	3000	270′	42′	18′6″	14	3500	2.8″ 6.6″
Dolphin	do.	1882	1884	do.	do.	1485	240′	32′	14′3″	15	2300	1.6″
Charleston Cruiser No. 2	Union Iron Works, San Francisco	1887	...	Building.	do.	3730	300′	46′	19′6″	18	7500	2.10″ 6.6″
Baltimore do. No. 3	Cramp, Philadelphia	1887	...	do.	do.	4413	315′	48′6″	21′	19	10500	4.8″ 8.6″
Newark do. No. 1		...	...	Not begun.	do.	4083	310′	49′2″	20′6″	18	8500	12.6″
Gunboat No. 1	Cramp, Philadelphia	1887	...	Building.	do.	1700	230′	36′	15′	16	3300	6 6″
do. No. 2	Columbia Iron Works, Baltimore	1887	...	do.	do.	870	175′	31′	12′6″	13	1300	4.6″
Dynamite Gun Cruiser		1887	...	do.	do.	...	239′	26′6″	7′6″	20	3200	3.10½″ D
Cruiser No. 1	Not yet designed	...	...	.....	do.	5000	...	...	...	19	...	.....
do. No. 2	do.	...	...	.....	do.	5000	...	...	...	19	...	.....
Gunboat No. 1	do.	...	...	.....	do.	1700	..	..	...	16	...	.....
do. No. 2	do.	...	...	.....	do.	1700	...	...	...	16	...	.....
1st-Class Torpedo Boat	do.	...	...	.....	do.	108	...	...	...	23	...	2 R.F. Gu
Stiletto, 2d-Class Torpedo Boat.	Herreshoff, Bristol	...	...	.....	Wood.	356	90′	11′	3′	22.9	560	.....
Floating batteries, rams and other naval structures for coast defense												

HE NEW NAVY.

	Beam.	Draught. Mean.	Speed.	I. H. P.	Armament. (All have Secondary Batteries.)	Armor, Side.	Armor, Turret.	Total Estimated Cost.	Authorization. Date of Act.	Remarks.
0′	60′	18′	13.¼	4100	4.10½″	12″ Steel.	16″ Steel.	$2,300,970	....	....
0′	55′6″	14′2″	10.5	1426	4.10″	7″ W. I.	11½″ W. I.	1,637,110	....	....
0′	55′6″	14′2″	10	1600	4.10″	7″ Steel.	11½″ Steel.	1,590,930	....	....
0′	55′6″	14′2″	10	1600	4.10″	7″ Steel.	11½″ Steel.	1,592,849	....	....
0′	55′6″	14′2″	10	1600	4.10″	7″ Steel.	11½″ Steel.	1,891,077	....	....
..	...	...	17	...	4.10″ 6.6″ } Automobile	.....	.....	*2,500,000	August 3, 1886	....
..	...	...	17	...	2.12″ 6.6″ } Torpedoes.	.....	.....	*2,500,000	do.	....
		Maximum.								
15′	48′2″	20′6″	15	5000	4.8″ 8.6″	.....	.....	1,576,854	1882	Twin Screws.
270′	42′	18′6″	14	3500	2.8″ 6.6″	.....	.....	1,031,225	1882	....
270′	42′	18′6″	14	3500	2.8″ 6.6″	.....	.....	1,031,225	1882	....
240′	32′	14′3″	15	2300	1.6″	.....	.....	460,000	1882	....
300′	46′	19′6″	18	7500	2.10″ 6.6″ }	.....	.....	*1,017,500	March, 1885	Twin Screws.
315′	48′6″	21′	19	10500	4.8″ 8.6″ } Automobile	.....	.....	*1,325,000	do.	do.
310′	49′2″	20′6″	18	8500	12.6″ } Torpedoes.	.....	.....	†1,300,000	do.	do.
130′	36′	15′	16	3300	6 6″ }	.....	.....	*455,000	do.	do.
175′	31′	12′6″	13	1300	4.6″ }	.....	.....	*247,000	do.	....
139′	26′6″	7′6″	20	3200	3.10½″ Dynamite.	.....	.....	*350,000	August, 1886	....
..	...	...	19	...	....	.....	.....	†1,500,000	March, 1887	....
..	...	...	19	...	....	.....	.....	†1,500,000	do.	....
..	..	...	16	...	....	.....	.....	†550,000	do.	....
..	...	...	16	...	....	.....	.....	†550,000	do.	....
..	...	...	23	...	2 R.F. Guns, 5 Torped.	.....	.....	†100,000	August, 1886	....
30′	11′	3′	22.9	560	....	.....	.....	25,000	purchase authorized.	
.....	.....	.....	.....	.....	....	.....	.....	2,000,000	expenditure authorized.	

* Contract price for hull and engines only.
† Limit of " " " " " "


Time in days
Methods of Drying Gun Cotton
Percentage of moisture
○ — 1.
⊙ — 2.
△ — 3.
X — 4.
V — 5.
• — 6.
● — 7.
M — 8.
Y — 9.
□ — 10.

BOOK NOTICES.

THE FALL OF MAXIMILIAN'S EMPIRE AS SEEN FROM A UNITED STATES GUNBOAT. By Seaton Schroeder, Lieutenant U. S. N. New York: G. P. Putnam's Sons.

Lieutenant Schroeder places in an attractive light many facts and incidents connected with the decline and fall of Maximilian's reign in Mexico. His exposition of the attitude of the United States towards the contending governments forms an admirable accompaniment to the story of the part taken by the United States Steamer Tacony before Vera Cruz during the last days of the Empire. The latter is the chief topic of the narrative, and it will prove pleasant reading to the public, and more particularly to naval officers. While the presence of the Tacony at Vera Cruz and the conduct of Commander Roe exercised little force upon the great events then transpiring, it seems clear that they served to give effect in an important quarter to the policy of the United States. We find in the measures of Commander Roe a striking instance of the judicious influence in national troubles of a well-trained naval officer, preserving abroad the neutrality of his flag, but defending its rights, aiding his countrymen among belligerents, ameliorating the distress incident to war, and securing in a large degree the respect and friendship due to the just course of his country. P. F. H.

TRAITÉ THÉORIQUE ET PRATIQUE DE LA REGULATION ET DE LA COMPENSATION DES COMPAS, AVEC OU SANS RELÈVEMENTS. Par A. Collet, Lieutenant de Vaisseau, Répétiteur à l'École polytechnique (Honorary Member U. S. Naval Institute).

Challamel Ainé, No. 5 Rue Jacob, has published a second edition of this well-known and valuable treatise on the marine compass, a copy of which has been gladly received by the Institute.

PUBLICATIONS OF CAST-STEEL MANUFACTORY OF FRIED. KRUPP, ESSEN, GERMANY.

The Institute has received through the courtesy of Messrs. Thos. Prosser & Son, the New York agents of Mr. Fried. Krupp, interesting pamphlets and plates showing the firing tests of the 28-cm. gun against compound plates 39.5 cm. in thickness; also results with the 40 cm. (120-ton) gun. Three fine photographs of the 120-ton gun were also presented to the Institute.

MATERIAL FOR FIELD ARTILLERY FOR U. S. ARMY. By Lieutenant A. D. Schenck, First Lieutenant Second Artillery.

A brochure, printed at the U. S. Artillery School, containing much interesting information. J. W. D.

BIBLIOGRAPHIC NOTES.

ALMANACH FÜR DIE K. K. KRIEGS-MARINE. (Issued by the publishers of the Mittheilungen aus dem Gebiete des Seewesens, Gerold & Co., Vienna.)

This little annual, just received, contains, as usual, besides the ordinary matter found in almanacs, a large proportion of useful information, some specially relating to local affairs of the State, and much of general interest, in a compact and readily accessible form.

PART I. contains very complete conversion tables for changing English weights, measures, pressures per square inch, feet per second, etc., into the corresponding equivalents in the metric system. The tables are of daily use to English-speaking people who read the technical papers published on the Continent, and to foreigners who read American and English publications.

PART II. contains tabulated data relating to the guns used by ten principal European powers, and a pictorial diagram showing the armor-piercing power of these weapons.

PART III. has a list, corrected to November, 1886, of all vessels of all descriptions belonging to the governments of twenty-nine countries, the list finishing up with Belgium and Venezuela, each of which has one vessel. With the name of each ship are given the principal data relating to hull, machinery and armament.

We notice several errors in the data relating to the ships of the U. S. Navy. For example: the Lancaster is credited with 2000 I. H. P. and 5 knots speed. This should be 1100 I. H. P. and 9.5 knots. The Alert is given 656 I. H. P., *i. e.* about 100 I. H. P. more than the engines were designed for, and the speed is given as 8 knots, when she makes 10 knots with about 500 I. H. P. Her sister-ship Ranger is also given 656 I. H. P., but only 6 knots instead of 10. (The errors in the I. H. P. of the two latter ships were probably copied from "King's War Ships," etc., 1881, but the corresponding speeds (10½ knots) there given were not copied.)

PART III. has also a table showing the number, rank, grade, etc., of officers and men attached to each ship in commission in the Austrian Navy.

PART IV. is entirely taken up with the tables of pay, allowances, commutations of quarters and pecuniary compensations for every conceivable accident or incident of service, and pensions of all descriptions, all arranged in a most elaborate system; and, we must add, apparently just to a degree. The officers, line and staff, are divided into classes according to rank, and the pay and allowances, etc., regulated for these classes. The compensation appears small; but if, as in the English service, the age of officers is so much less for a corresponding rank than in our Navy, the aggregate pay received by an Austrian officer would compare favorably with ours.

PART V. contains the list of officers in the service, with rank, etc., as in our Naval Register, and also designates those who have received special honors, decorations, medals, etc.—a feature which might be introduced with advantage in our Annual Navy Register, where an officer who has received the thanks of Congress is not distinguished in any way from the others, and one who has gained rank by gallant conduct is put down in the same way as his neighbor on the list who has reached his position by simply doing routine duties.

W. F. W.

AMERICAN INSTITUTE OF MINING ENGINEERS, TRANSACTIONS.

FEBRUARY, 1887. Valuable article on magnesium carbonate as a non-conductor of heat.

The following table presents the results of experiments made :

Description of the 2-inch Pipe Covering.	Diameter in inches.	Weight per ft. in ounces.	Thermal units conducted per lineal ft. per hr.
1. Hair-felt, wrapped with twine, burlap jacket.	4½	12½	69.02
2. Sectional carbonate of magnesia, asbestos paper jacket, bands.	4½	20¼	75.29
3. Sectional carbonate of magnesia, canvas jacket, bands.	4½	20¼	75.68
4. Sectional mineral wool, asbestos paper, mineral wool, muslin.	5¼	28¾	76.68
5. Chalmer-Spence Co.'s covering, asbestos, hair-felt, paper.	4½	28¼	82.95
6. Shields & Brown's covering, asbestos paper, sheathing paper.	4½	27¼	84.65
7. Reed's covering, asbestos paper, felt paper.	4¼	26¾	89.62
8. Fossil meal pipe covering, fossil meal, organic fibre.	3¾	24	114.54

W. F. W.

ANNALEN DER HYDROGRAPHIE.

PART X., 1886. Cyclones in West Australia, March, 1882, and January, 1879. Cruise of the German squadron under command of Rear-Admiral Knorr along the coast of New Mecklenburg and New Hanover, and thence to Hong-Kong. Hydrographic notes on the island of Longa-Longa, east coast of Africa. Remarks on the harbor of Constantinople. Influence of the sun and moon on the trade-wind. On avoiding collisions at sea by placing the side lights at an angle of 45° with the top light. Meteorological and hydrographic notes.

PART XI., 1886. Measurement of the rise and fall of water. Cruise of the German corvette Albatross through the Caroline Islands. Reconnoitring cruise of the German corvette Habicht on the west coast of Africa. Meteorological and hydrographic notes.

PART XII., 1886. Measurement of the rise and fall of water (concluded). Hydrographic notes and sailing directions for the Bismarck Archipelago. Current between the Mediterranean and the Black Sea. New method of finding course and distance in great-circle sailing. Meteorological and hydrographic notes.

ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

15TH YEAR, 1 VOL. Thunderstorms, and observations for the same, by Professor F. G. Hahn. Hydrographic observations taken by H. I. M. S. Olga on her voyage through the Bismarck Archipelago from Meoko to Nusa and thence to Matupi. The Empress Augusta

River, Emperor William's Land. Remarks about Montevideo and Charleston, S. C. Contribution to the theory of coast-currents and counter-currents. Deep-sea soundings on the coast of Nova Scotia and Newfoundland (U. S. S. Albatross). Deep-sea water bottles with deep-sea thermometers. Prediction of a chronometer rate, by Prof. D. Börgen. Report of temperature-coefficient of chronometers kept in the observatory of Wilhelmshafen during the winter 1885 and 1886. June rains in Japan, 1885 and 1886, by E. Knipping, Tokio. Notices, hydrographic tables.

ANNALEN DER HYDROGRAPHIE UND MARITIMEN HYDROGRAPHIE.

15TH ANNUAL SERIES, 2D VOLUME, 1887. About thunder-showers and observations therefor (conclusion), Dr. F. G. Hahn. Tourabaya and its mercantile relations, by Commander H. I. M. S. Adler. Hydrographic notes for the Marshall Islands, by Commanders H. I. M. SS. Bismarck and Albatross. Notes about Colachel and St. Helena, by Captain Herndorf, German barque Werner. Notes from the voyage of the German ship Herrman, Kingston, South Australia. Observations for temperature of the ocean on the route Hamburg, London, Lisbon and Southwest Africa. Deep-sea soundings, North Atlantic Ocean (U. S. S. Essex). Typhoons in the China Sea. September typhoons of 1886 in Japan. Influence of magnetic forces on the rate of chronometers. Small notices. Tables.

ENGINEER.

DECEMBER 24, 1886. Comparison of English and French Navies, together with list of all the armorclads belonging to each. Trial of the submarine torpedo boat Peacemaker at New York City.

This boat is propelled by a 14 I. H. P. steam engine, with a Honigmann fireless boiler, and made a successful trip in the Hudson River for half an hour under the surface, descending as deep as 40 feet, and describing various curves. There were three persons on board, and the air remained reasonably pure, making it probable that the voyage could have been continued for several hours. It is claimed that the boat can maintain a speed of 8 knots per hour, for several hours, with one charge of caustic soda in the boiler.

Editorial on liquid fuel, pointing out in detail the difficulties yet to be overcome before such fuel can come into general use on board ship at sea.

JANUARY 7, 1887. Torpedo vessels in Europe.

	No.	Tons.	Cost in £.
Great Britain,	156	23,902	1,460,000
France,	143	20,450	1,253,000
Germany,	150	14,597	900,000
Russia,	115	5,104	312,000
Italy,	89	7,966	500,000

Many of the English boats are 38 to 40 metres in length, but the French only 25 to 30 metres.

JANUARY 14, 1887. El Destruidor, torpedo cruiser.

The vessel is a twin-screw cruiser, 200 feet long, 25 feet beam, 13 feet depth, built of high-tension steel. Every piece of steel or iron in her is galvanized. She has a ram-bow and a bow-rudder, the latter partly to assist manœuvring, and partly to act as a lee-board when under sail. The stern-rudder is of a new type known as Thompson and Biles's "patent sternway manœuvrer," with a surface of 80 square feet, and is considered an improvement on the ordinary balanced rudder, and has the advantage of giving more complete control of the vessel when going full speed astern. The steering gear works both rudders and the capstan. There are 39 water-tight compartments. The engines are in two separate compartments and the four boilers in four, and the whole surrounded by coal bunkers. The engines are triple-expansion, and the boilers locomotive of 3800 H. P., with air pressure of 2¼ inches. The consumption of coal on a four-hour trip was only at the rate of 2.1 pounds per I. H. P. per hour, showing that the vessel could steam at full speed for about 700 knots. At 11½ knots she could go 5100 knots. There are three masts, made to hinge down and fitted with fore and aft rig. There are two bow and one stern torpedo tubes, and two broadside tubes to be fitted on the upper deck. There are one 9-cm. pivot gun on the forecastle, four 6-pounder rapid-firing broadsides, and two 37-mm. Hotchkiss forward.

FEBRUARY 11. The Nordenfeldt submarine boats for Turkey.

These boats have two functions: 1st. To steam at the surface; 2d. Underneath. In the first case the two cylinder engines get steam from a boiler fired in the usual way. The armament consists of two 1-inch Nordenfeldt guns. In the second case, when it is desired to sink, water is let into three ballast tanks, one at each end and one amidship, the two former holding about 15 tons and the latter about 7, until nothing but the glass conning-tower is visible. While the tanks are filling, the furnaces are closed to put out the fires, and the piece of funnel connecting the boiler with the outboard opening in the vessel's side is removed and the opening closed. Steam is now taken from a storage reservoir holding about 30 tons of water previously heated by steam from the boiler until its vapor has a tension of 150 pounds. This, with the vacuum, is sufficient to drive the boat 30 or 40 miles. To sink lower there are two screws on vertical shafts, one at each end of the boat. There are two movable fins at the bow to assist in controlling the movement of the boat under water. The action of all three screws is regulated by the captain from the conning-tower. The data of the Turkish boats are: Length, 100 feet; beam, 12 feet; displacement, 160 tons; I. H. P. 250, with 100 pounds steam; coal capacity, 900 knots at moderate speed. The details of the torpedo armament have not been disclosed.

Firing trial of the 110½-ton B. L. Elswick gun, with illustration of the gun, etc. The Mougin disappearing turret (illustrated).

W. F. W.

ENGINEERING.

DECEMBER 24, 1886. Trial of the submarine torpedo boat Nautilus in the Tilbury docks.

The boat is cigar-shaped, 60 feet long and 8 feet diameter, with total displacement of 52 tons. There are two Edison-Hopkinson motors supplied from 180 Elwell-Parks storage cells, each of about 4 H. P. hours. The boat was tried successfully at slow speed in the dock, on the surface, and below water, and performing various evolutions. It descended to a depth of 28 feet (measured from top of boat to surface). Expected speed 8 to 10 knots, and revolutions 750. It is intended to carry 6 men, and the air contained in the boat is found sufficient for a two-hours' trip without renewal or purification.

JANUARY 7, 1887.

The second-class steam cruiser Thames, of the Amphion class, made her contractor's trial of the engines on Tuesday. Draught forward, 13 feet 5 inches; aft, 17 feet 3 inches; steam, 97 pounds; revolutions, starboard 108, port 110; total I. H. P., starboard 2166, port 2329; speed, 17 knots.

The Allan air-spring pressure gauge; sketch and description with latest improvements. New Russian cruisers.

The Russian Government is reported to have decided to construct six more vessels of the Vitiaz and Rinda class. They are 265 feet long, 45 feet beam, and 14 and 18 feet draught fore and aft. Compound engines 3600 I. H. P., and speed 16½ knots; can steam 3500 knots at 14 knots, 5000 at 13 knots, 5750 at 12, and about 10,000 knots at 8 or 10 knots per hour. Armament, ten 6-inch rifles, eight Hotchkiss, and four 4-pounders; also Whitehead torpedoes and two torpedo-cutters 32 feet long, armed with Baranovsky guns.

Fire boats. Paper read before the American Society of Mechanical Engineers, by Mr. Wm. Cowles, Engineer, N. Y. (Member of Naval Institute, and late Assistant Engineer, U. S. N.).

Three pages working drawings and page of data relating to five fire boats built in this country and England, designed by himself and others in the United States and in England.

FEBRUARY 4. Clyde shipbuilding and marine engineering for 1886.

The most notable feature in this connection is the extraordinary extent to which the triple-expansion engine has been adopted, both in war ships and the merchant marine. Almost every screw steamer sent out of the Clyde shipyards last year was fitted with this kind of engines. The total output amounted to upwards of 170,000 I. H. P., besides a number of comparatively new compound engines altered to triple-expansion.

Messrs. Denny & Co. have satisfactorily proved that the practical adoption of the principle of quadruple expansion in marine engines is attended with even a still greater economy. Some engineering firms are scarcely yet disposed to go beyond steam pressure of 140 pounds per square inch in boilers working triple-expansion engines, but with Messrs. Denny & Co. 160 pounds is now quite common. Their quadruple-expansion engines, now building, are designed for working up to 170 to 180 pounds pressure. Such engines with 180 pounds pressure are no new thing on the Clyde. The engines of the yacht Rionnag-na-Mara (already described in this journal), built at Greenock, have given excellent results. On trial, with 180 pounds pressure and twelve expansions, the coal consumption was only 1⅛ pounds per I. H. P., best Welsh coal. On a cruise of 3638 knots, with steam sometimes as low as 145 pounds, the consumption of coal of mixed average quality did not exceed 1.43 pounds per I. H. P., including coal used for steam for steering gear and windlass. The use of mild steel both for forgings and castings in engine construction is one of the most marked features in marine engineering practice at the present day. During the year was built the torpedo vessel El Destruidor, which on trial reached the speed of 23 knots, the greatest ever yet attained by any steam vessel with full equipment on board. The improvements that have been going on during the past few years in ship construction and marine engineering, especially since the introduction of steel, have neither been few nor unimportant. Such plant as is now in use in the best-equipped establishments renders it possible to manipulate plates and angles for hulls with such rapidity that it is now possible for a vessel of almost any dimensions to be built and fitted out ready for sea within a period of twelve months. There is no doubt that the

Clyde shipyards and engine shops are now in a condition of remarkable efficiency, owing to the development which has taken place in labor-saving appliances of almost every kind.

FEBRUARY 11. On seagoing torpedo boats; urging the importance of seaworthiness in torpedo boats. W. F. W.

FRANKLIN INSTITUTE JOURNAL.

MARCH, 1887. The microscopic structure of iron and steel, by F. Lynwood Garrison, F. G. S.

INSTITUTION OF CIVIL ENGINEERS, LONDON.

VOL. LXXXVII, 1886–87, Part I. The discussion of electric-light houses.

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

No. CXXVII. French operations in Madagascar, 1883–1885, by Captain S. Pasfield Oliver, late R. A., F. R. G. S. Barnett's patent water brakes, by Mr. Frederick Barnett, C. E. Colonel Mulock's patent for driving punkahs, by Colonel T. Edmonds Mulock, C. B. Coast defense, by Colonel Schaw, R. E., Deputy Director of Works for Fortifications. Small arms for field artillery, by Major J. D. Douglas, R. A. B. F. T.

JOURNAL DU MATELOT.

No. 5, FEBRUARY 6, 1887.

On the 20th of January there was launched at La Seyne the first of fifty of a new class of torpedo boat. It was commenced in 1886. Its number is 99. The principal dimensions of this little boat are: 115 feet long, 11 feet wide, 8 feet deep. Its displacement is, with everything on board, but 54 tons; this includes crew, bunkers filled, and four automobile torpedoes. Two of these torpedoes are placed in the launching tubes, whose height above the water-line has been raised 15 inches to facilitate launching the torpedoes in rough weather. The two other torpedoes are kept in reserve. These torpedo boats will attain a speed of 20 knots, and must maintain this speed for three consecutive hours during the trials, which will take place in fine, clear weather. According to a special correspondent this boat sits well in the water. The commanding officer's post is well sheltered from the sea. The machinery was tried January 21, and the boat started on a cruise January 29. The two first trials have given great satisfaction.

No. 6, FEBRUARY 13, contains an account, with illustrations, of a boat-detaching apparatus designed by M. Rees.

A paragraph says: "The torpedo-boat exercises at Toulon will commence April 1st, 1887, and will continue six weeks."

LE YACHT.

DECEMBER 11, 1886. P. 448: Plan of seagoing torpedo boat building for Chinese Government, with partial description. P. 449: Picture of the English Polyphemus. Commences an article entitled

"Studies on the American Navy," being extracts from and comments on the writings presented to the U. S. Naval Institute. This number dwells upon Admiral Simpson's able article.

DECEMBER 18. P. 453: "Studies on the American Navy," taking up the papers of Lieutenant Calkins and Ensign Rodgers.

DECEMBER 25. P. 463: Trial of El Destruidor, Spanish torpedo boat. P. 465: "Studies on the American Navy," reviewing the papers of Commander Hoff, published in 1884. A memoir on naval tactics, by Lieutenant-Commander Elmer, 1884, and Commander Taylor's paper of March 17, 1886.

JANUARY 1, 1887. P. 4: The submarine vessel Nautilus—plans and description.

JANUARY 8. P. 9: "Studies on the American Navy"—end.

The article is finished with these complimentary words: "May these imperfect outlines and summaries attract the attention of the French public to the publications of an association so competent as the U. S. Naval Institute. We have but just touched upon a very small number of the articles emanating from its members, but all the others give equal evidence of conscientious research and are filled with original views which are generally to the point."

P. 14: The fighting Navy of Russia. P. 15: Plans of the Russian ironclad Catherine II.

JANUARY 15. P. 18: Explosive projectiles. P. 21: Picture of the Gabriel-Charmes, type of a new class of single-gun gunboat constructed at La Seyne.

JANUARY 22. P. 27: Double-screw seagoing torpedo boat, constructed by Thomson, on the Clyde, for the Russian Government. Plans, views and description thereof.

JANUARY 29. P. 36: Illustration—Le Déroulède, French seagoing torpedo boat built at Havre.

FEBRUARY 5. P. 44: Plans of new U. S. vessels. P. 45: Jury rudder, by Captain Swan, of San Francisco.

FEBRUARY 12. P. 51: Launching of the ironclad Pelayo, built at La Seyne for the Spanish Navy.

FEBRUARY 19. P. 60: Elevation and plans of the Pelayo, with a general description.

FEBRUARY 26. P. 65: The canal from Paris to the sea.

MARCH 5. P. 75.

The following ships will be commenced this year for the French Navy: Three cruisers of the Dupuy de Lôme class, 4162 tons each; three cruisers of the second class, 3000 tons each; three cruisers of the third class, type Surcouf, 1877 tons each; eight contre-torpilleurs, type Ouragan; twenty-four torpedo boats first class.

P. 80: Contrasting the principal Transatlantic lines—Cunard, German Lloyd, and French line.

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS.

VOL. XIV., Nos. 9 and 10. Atmospheric electricity and the weather, by Captain C. von Bermann. Review of Admiral Freemantle's article on naval tactics. Rapid-firing cannon. Reorganization of the Spanish Navy. New Schichau torpedo boats for China and Italy. Steam-steering-apparatus torpedo boats. The French Navy—trial of the Duguesclin. Sea torpedo boat Ouragan. The Turkish Navy. The Danish turret ship Iner Hvitfeldt. The 110-ton gun for the Benbow.

With these numbers appears a description of the cruise of the Austrian corvette Saida in the Atlantic and Pacific Oceans in the years 1884–1886. This report contains full and authentic information in regard to the exports and imports of the places visited. The information is of importance to the service as well as to business men.

NOS. 11 and 12. Budget of the French Navy for 1887, and the 140,000,000 credit of Admiral Aube. Rules for handling the machinery and boilers of the Schichau torpedo boats. The Russian Navy. The English Navy—armored cruisers Australia and Undaunted. A new submarine torpedo boat. New cruisers for the Chinese Navy. Description of the trial of the Russian torpedo boat Wiborg. The French Navy—first-class cruiser Alger. The Medford cannon.

NORSK TIDSKRIFT FOR SOVAESEN.

NO. 3 of 5TH ANNUAL SERIES. Naval tactics (conclusion); compilation from English, French and Italian works on the same subject. Bursting of the guns on board H. M. S. Collingwood, by Premier Lieutenant G. March. Electric log of Commandant Fleuriais; from the French, by Premier-Lieutenant E. Steenstrup. On carrying petroleum in bulk on board steamers; from the *Nautical Magazine*. Lecture before the "Sea Military Society" (Naval Institute), by Com.-Captain Wisbeck, upon "the history of the development of great guns in navies during the years 1860 to 1870." After treating that subject, a treatise on the same subject for the Swedish Navy follows. Reviews of foreign articles: Le Tonnant, garde-côtes cuirasse (French) Puragang, torpedo boat (*Mittheilungen aus dem Gebiete des Seewesens*); brown powder from Rhenish Westphalia Powder Co. (*Deutsche Heereszeitung*); electric boat from *Iron*; electric life buoy.

Sinking of the steamer Oregon. Foreign notes: New French cruisers. Chinese torpedo boat; the Spanish Navy. Official Miscellany.

Memorial of Commander Henrik Jacob Müller. Sea tactics. Theory of the Bremms slide-valve gear. Classification of the French fleet. Equinoctial storms. Foreign notes: American torpedoes; the English armored ship Benbow; the German swift-dispatch boat Greif; experiments with English armored ship Resistance. New submarine boat. Official miscellany. W. F. W.

PROCEEDINGS OF THE ROYAL ARTILLERY INSTITUTION, WOOLWICH.

FEBRUARY, 1887. The protection of heavy guns for coast defense, by Captain G. S. Clarke, R. E. The Nile expedition of 1885, lecture by Colonel F. Duncan, C. B., M. P., R. A. The attack formation of infantry, by Lieutenant-Colonel G. B. Macdonell, R. A.

REVUE DU CERCLE MILITAIRE.

No. 4, DECEMBER 25, 1886. The organization of columns of attack having in view the destruction of obstacles accumulated by the defense.

VOL. II., NO. 1, JANUARY, 1887. Report by General Berthier on the duties of the general staff, Army of the Alps, 1796. End of article on organization of columns of attack. Trial of Nautilus, submarine boat, in the East India docks, London.

Dimensions, 62 feet long, 8.6 feet greatest diameter, being shaped like a cigar. The motive-power is an electric engine of 45 H. P.; speed, 19 knots.

No. 2, JANUARY 8. Conclusion of General Berthier's report; also a description of new equipments for foot soldiers in French Army.

No. 3, JANUARY 15. The velocipede in the Army.

No. 4, JANUARY 23. An article on the new instructions (for an engagement) given to the German infantry, containing general principles for the offensive; school of the soldier, of the company, of the battalion and of the regiment. There are many interesting articles in this number under the heading "Chronique militaire," such as: The new German repeating rifle; Schichau's torpedo boats; the Schulhoff repeating rifle, and the official programme of instructions for the troops of different corps of the Italian Army for the summer manœuvres of 1887.

No. 5, JANUARY 30. Complete detail of the new Spanish fleet.

No. 6, FEBRUARY 6. Account of trial of Nordenfeldt submarine torpedo boat at Constantinople.

No. 7, FEBRUARY 13. Rules regulating the use of the repeating rifle in the German Army, dated February 3, 1887. The new German Army equipment for foot soldiers. Trial of a torpedo boat at Trieste.

It is stated that a speed of 23 knots was obtained, and that by making some changes a greater speed would be developed.

No. 8, FEBRUARY 20. Description and pictures of new French knapsack. The manœuvres of the German fleet, August and September, 1886, giving the names of vessels composing divisions. The 110-ton and 68-ton guns.

No. 9, FEBRUARY 27. The Italians at Massouah, giving plans and description. The fortifications on the Meuse rendered necessary by the change in artillery.

No. 10, MARCH 6. The defenses of the English colonies.

Japan has ordered 150 automatic torpedoes from Schwarzkopf, and ten 34-centimetre and twenty 12-centimetre guns of Krupp. An opinion by a Russian general on the inconvenience of the repeating rifle. D. H. M.

REVUE MARITIME ET COLONIALE.

JANUARY, 1877. Description of the Province of Battambang. The Legion of Honor (continued). Submarine navigation applied to the defense of ports. Historical studies of the French Navy (continued). The budget of the English Navy (continued). Naval chronicle.

FEBRUARY, 1887. Oyster culture in 1886. Report upon the gyroscope-collimator. The Legion of Honor (continued). The cyclones in the Gulf of Bengal. Historical studies of the French Navy (continued). Description of the Province of Battambang (conclusion). The Scotch fisheries in 1886. The budget of the English Navy (conclusion). Naval chronicle.

MARCH, 1887. The Austrian expedition to Jan-Mayen Island. Determination of the deviation of the vertical line upon the coasts of France, and its effect upon the determination of the time. The Legion of Honor (continued). Appendix to the article on the movement of the top. Naval chronicle. B. F. T.

RIVISTA MARITTIMA.

NOVEMBER, 1886. The cruise of the Vettore Pisani (continued). Navigation notes: The Galapagos Islands to Callao, Callao to Honolulu, Honolulu to Manila. The Italian Navy estimates (continued). Plans and descriptions of the four U. S. cruisers authorized by act of March 3, 1885.

RIVISTA DI ARTIGLIERIA E GENIO.

JANUARY, 1887. Note on a formula of penetration derived from experiments made at Metz.

S is the area of the circle of perforation, χ, β two constants depending on the substance; then $\rho = S.a\,(1 + \beta v^2)$. R. C. S.

REVISTA MARITIMA BRAZILEIRA.

AUGUST and SEPTEMBER, 1886.

On the 23d of last July there was made in England the first trial of the submarine torpedo boat invented by the distinguished American engineer Ericsson. It was made at Milford Haven, under direction of Second-Lieutenant Gladsone, of the gunnery school-ship Vernon. The boat is 9.14 metres long, and threw a projectile of one ton weight. The first trial was made at a depth of 3.35 metres, and the projectile traversed a distance of about 155 metres. The inventor thinks it possible to obtain a range of 300 metres if necessary. W. F. W.

Notes of travel. The binocular sextant. Naval tactics. Organization of the meteorological service in Europe. Modern artillery.

The torpedo. Miscellaneous notes: On the use of oil for calming the sea; the Inconstant, French dispatch boat first class; foreign seamen in England; the Popoffkas; the Ericsson submarine boat; the Italian fleet; the English naval and military manœuvres at Milford Haven. Necrology. Notices to mariners.

REVISTA DE MARINA (VALPARAISO).

NOVEMBER, 1886. Routine on board H. M. ships (British). The torpedo question (concluded). Data, hydrographic, commercial and administrative, relating to our ports, etc. Lunar distances. The Society Islands, Tubnaï and Rapa. Means of preventing syphilis among the crews of the naval vessels of the Republic. Naval prize essay. Decision of the judges. On the reorganization of the *personnel* of our fleet in all its branches. Some thoughts concerning ships with armor belts. The Esmeralda. Notes: The Orlando, belted cruiser; trials of the Italia, Italian armorclad; electric steering apparatus (Washburn system); the Orion (Spanish torpedo boat); movements of the ships of the Fleet. W. P. W.

The 111-ton guns were fired for the first time on board a ship and caused no damage whatever to the machinery. After this the engines were tried, and the speed obtained was 13.5 knots with 12 boilers, and 17.1 knots with 26 boilers and 85 revolutions. Temperature in fire room 72° C.

Subsequently the trials were ended in the latter part of May, 1886, and a speed of 18 knots was obtained, but could only be maintained during the first hour of the trial. The mean speed for the rest of the time was only 17.8 knots. Instead of 96 revolutions, only 89 were obtained, and the calculated I. H. P., 18,000, was not developed. W. F. W.

TRANSACTIONS OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

NOVEMBER, 1886. Valuable article on the high-pressure hydraulic system of distributing power in cities, etc., showing the advantages of this over other systems in certain cases. W. F. W.

UNITED SERVICE GAZETTE.

JANUARY 15, 1887. A new torpedo. Vexed questions in naval construction.

JANUARY 22. Machine guns in the field. Autumn manœuvres.

JANUARY 29. Naval strategy.

The British Government has, it is stated, consented to lend six gunnery instructors to the Chinese for the period of three years, with the option of the renewal of their services at the end of that period, should they be required. These are not the only British naval officers lent, or to be lent, to the Chinese Government. They are only additional, and are specially employed for instruction in gunnery.

FEBRUARY 5. Armed cruisers.

The torpedo boat catcher, built by Messrs. Thomson, of Clyde Bank, Glasgow, for the Spanish Government, made the run from Falmouth to Cape Finisterre in 24 hours, the mean speed being 21 knots. The vessel is 450 tons

displacement, and is propelled by two sets of three-cylinder engines, each in separate compartments. She carries several guns and has five torpedo tubes. Two rudders, one forward and one aft, have been fitted, to enable her to manœuvre quickly.

FEBRUARY 12. Coast defense by gunboats.

FEBRUARY 19.

As serving to show the activity in the Russian Navy at present, it may be mentioned that Messrs. R. Napier & Sons, of Glasgow, have just shipped for the armorclad Sinope, 10,150 tons, building at Sebastopol, the largest set of triple-expansion engines that have yet been made for a man-of-war. They are designed to indicate 12,000 horse-power without forced blast. The same firm have also dispatched three sets of triple-expansion engines, to indicate 2000 horse-power each, for gunboats building at Nicolaieff. At the Motala works the engines are being constructed for three other gunboats building at Sebastopol, while a fourth is being built and engined at Copenhagen. The Tchesme, a sister ship to the Sinope, has been launched, and the engines, of the compound type, are being fitted on board by Cockerill, of Belgium. Another battle ship like the Sinope, the Catherine II., is well advanced at Nicolaieff, the machinery for which will be supplied from the Baltic works, at St. Petersburg.

FEBRUARY 26. Magazine and repeating arms.

MARCH 5. Naval intelligence department. Hints on practical electric working.

MARCH 12. Serious naval scandal. Admiralty contracts. Prussian field artillery. The Navy estimates.

The final proof experiment with the first of the great guns for the Benbow was made at Woolwich on March 9, with complete success, two projectiles, each weighing 1800 pounds, having been fired with a charge of 1000 pounds of powder behind each. The projectile was discharged with an initial velocity of 2128 feet per second, and after the two shots the gun was found to be uninjured. This gun weighs 111 tons, and is the largest piece of ordnance ever fired in England. The carriage weighs 95 tons. The calibre is 16¼ inches, and the total length 44 feet. The gun is fired by electricity. On March 12 Captain Fitz-Gerald, R. N., lectured, at the Royal United Service Institution, on "Mastless Ships of War." The lecturer advocated immediately unrigging the present ironclads, leaving them only military masts.

MARCH 19. *Personnel* for submarine mining. The Navy estimates.

The estimated cost of building the new belted unarmored cruiser soon to be begun at Chatham Dockyard is £92,000, of which sum £29,000 will be expended in wages alone. The new vessel, which is intended to steam at 20 knots an hour, will, it is expected, be completed and launched during the present year. The Camperdown, a vessel of the central-citadel type, 330 feet long, 68 feet 6 inches beam, 10,000 tons displacement, had her contractor's trial, with natural draught, at Spithead on the 14th of March. The ship was under steam soon after 9 A. M., but full power was not developed until quarter to ten, when the patent log was hove overboard to check the result of her six hours' steaming, while the vessel was put on the first of her runs at the mile in Stokes's Bay. The Camperdown on this occasion drew 22 feet 3 inches forward and 24 feet 5 inches aft. (When all ready for sea, it is estimated that she will draw 26 feet 3 inches forward and 27 feet 3 inches aft.) The motive-power of the ship consists of two sets of three-cylinder vertical inverted compound engines in two separate compartments actuating twin screws. The steam in her boilers showed a pressure of 83.3 per square inch, while the vacuum in the starboard engines was 28.33, and in the port engines 28.29, and the revolutions

94.41 and 95.38 respectively. The indicated horse-power of the combined engines varied from 8500 to 9103, giving a mean total horse-power of 8605.94. The consumption of coal during the trial was at the rate of 2.11 pounds per horse-power per hour. The ship had four runs in Stokes's Bay, completing the first mile, which was with the tide, in a little over three minutes, or at a speed of 17.73 knots per hour. The second mile was run at the rate of 15 knots against the stream; the third at 17.30, and the fourth at 15.78—a mean rate of 16.30 knots for the four runs, which was considered very satisfactory. On the termination of the mile test, the vessel had a four-hours' continuous steam trial in the Channel, off the Isle of Wight, to the Needles and back. The machinery worked capitally all the time, the patent log at 4.15 P. M. registering a distance of 112 miles, traversed in the six and a half hours the vessel had been under steam. During the trial water troughs were tried under the stokeholes to check the fusion of the metal bars where much heat is developed, according to the plan used in the new torpedo boats. The telephone was also tested as a means of communication with the engine room. On March 16 the Camperdown was tested at continuous steaming and at the measured mile with forced draught. The ship drew 22 feet 4½ inches forward and 24 feet 4½ inches aft. She first had her four-hours' consecutive steam test, being at the end of this put on the measured mile, and finally experiments were made in turning, the vessel answering her helm with the utmost readiness and going about almost in her own length. With 88 pounds of steam in her boilers, and a vacuum of 26.93 in the starboard engines, and 27.43 in the port, there was a mean high pressure in the respective engines of 38.58 and 46.97, the low pressure in the same being 19.93 and 20.47 respectively. The number of revolutions per minute was 101.85, and the collective indicated horse-power 11,740.86. This is considerably above the rate contracted for, and everything that could be desired. The power developed from the engines realized a mean speed under forced draught of 17.144 knots, and under natural draught of 16.6 knots. The machinery worked easily and smoothly throughout all the trials, and the heat in the stokeholes was not excessive during the time of the forced draught, although the consumption of coal averaged 3.26 pounds per horse-power per hour. It is expected that the Camperdown will be ready for service about the end of next year.

B. F. T.

UNITED STATES NAVAL INSTITUTE,

ANNAPOLIS, MD., *April* 22, 1887.

At a meeting of the Board of Control of the United States Naval Institute the following resolutions were adopted:

Resolved, That by the death of Lieutenant John W. Danenhower, U. S. Navy, late Secretary and Treasurer and a member of the Board of Control, the Naval Institute has lost an officer whose fidelity, energy, and ability, in the discharge of the duties of his office, contributed in a large degree to the present prosperity and usefulness of the Institute.

Resolved, That Lieutenant Danenhower's character commanded the esteem and confidence of the members of this Board, and that the unvarying courtesy of his manner, the kindness of his disposition, and the generous qualities of his manhood endeared him to his associates as a friend.

Resolved, That the members of the Board of Control offer their respectful and profound sympathy to the family of the deceased.

By direction of the Board of Control.

P. F. HARRINGTON,
Commander, U. S. N.,
CHAIRMAN.

CHAS. R. MILES,
Lieutenant, U. S. N.,
SECRETARY.

NOTICE.

Owing to an unavoidable delay in receiving the decision of the judges, it has been deemed advisable to print the Prize Essay, without discussion, in the present number of the Proceedings.

The meeting for the discussion of the Essay at Annapolis, Md., will be held on October 14, 1887. The Corresponding Secretaries will hold meetings at their respective Branches for the discussion of the Essay at any convenient date, not later than October 14th. Members not able to attend any of the meetings may take part in the discussion by forwarding their remarks in manuscript to the Secretary and Treasurer, or to the Corresponding Secretary of any Branch, not later than October 13, 1887.

All MSS. of the discussion must be forwarded from the Branches to the Secretary and Treasurer before October 20, 1887.

By direction of the Board of Control.

CHAS. R. MILES, *Lieut., U. S. N.,*
Secretary and Treasurer.

NEW YORK, *May* 19, 1887.

SECRETARY, NAVAL INSTITUTE, ANNAPOLIS, MD.

Dear Sir: After examination of the five essays upon the Naval Brigade, submitted to us for decision, we have the honor to state that we consider the essay bearing the motto "In hoc signo vinces,"* entitled to the prize.

In our opinion the remaining essays stand in the following order of merit:

First—"He who can get more from his men than can his opponent from his, is always at an advantage."† Deserving honorable mention.

Second—"Aut nunquam tenta aut perfice."‡ Deserving honorable mention.

Third—"J'ai pris mon parti."

Fourth—"Necessity is the mother of invention."

Respectfully submitted,

J. S. SKERRETT,
Captain, U. S. N.
CHARLES HEYWOOD,
Major and Brev. Lt. Col., U. S. M. C.
J. W. MILLER.

* By Lieut. C. T. Hutchins, U. S. N. † By Lieut. T. B. M. Mason, U. S. N.
‡ By Ensign Wm. Ledyard Rodgers, U. S. N.